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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

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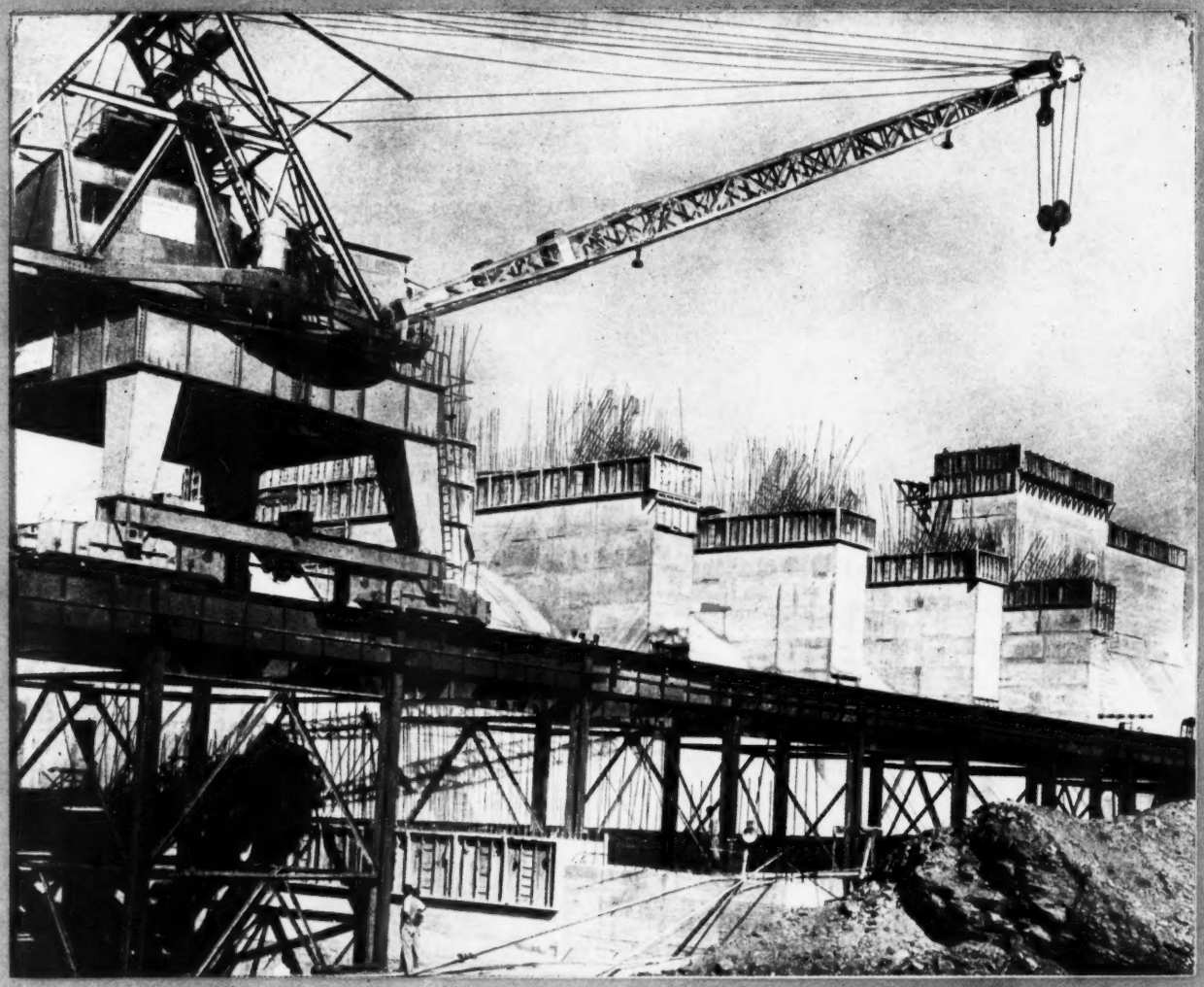

40 TON FULL REVOLVING GANTRY CRANE AT PANCHET HILL DAM OF D.V.C. SUPPLIED BY EASTERN EQUIPMENT & SALES LTD., CALCUTTA

(see page 21)

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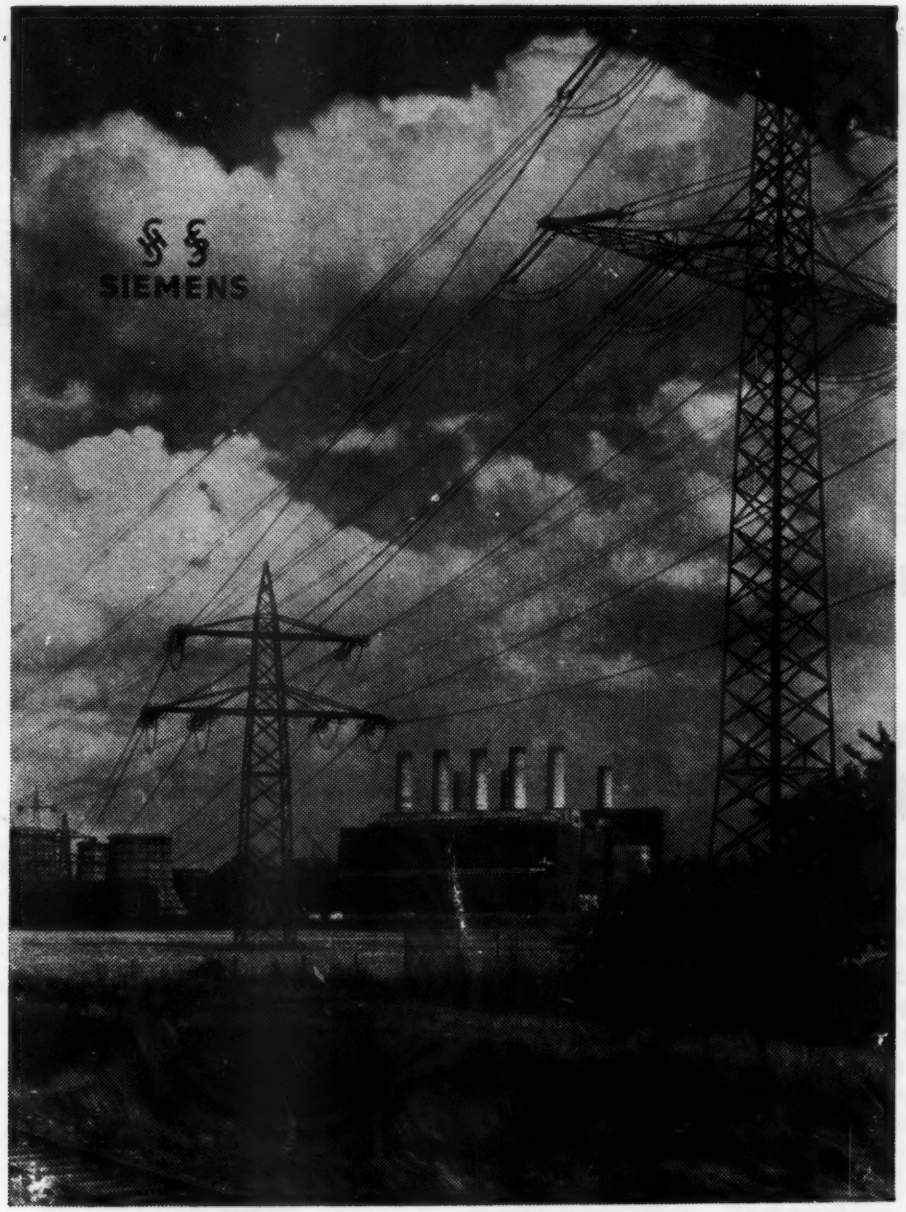

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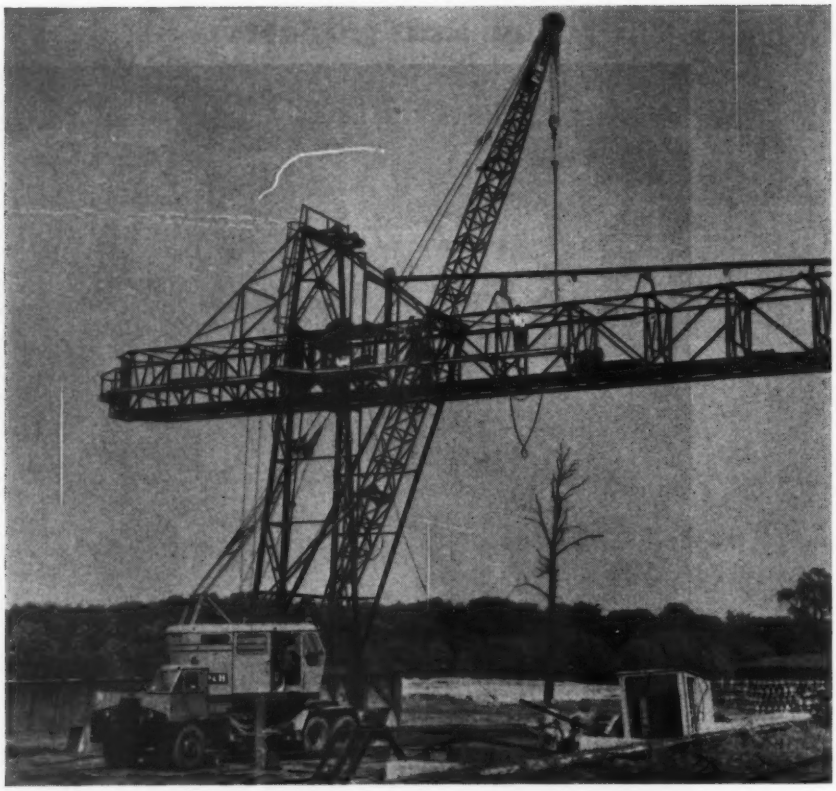

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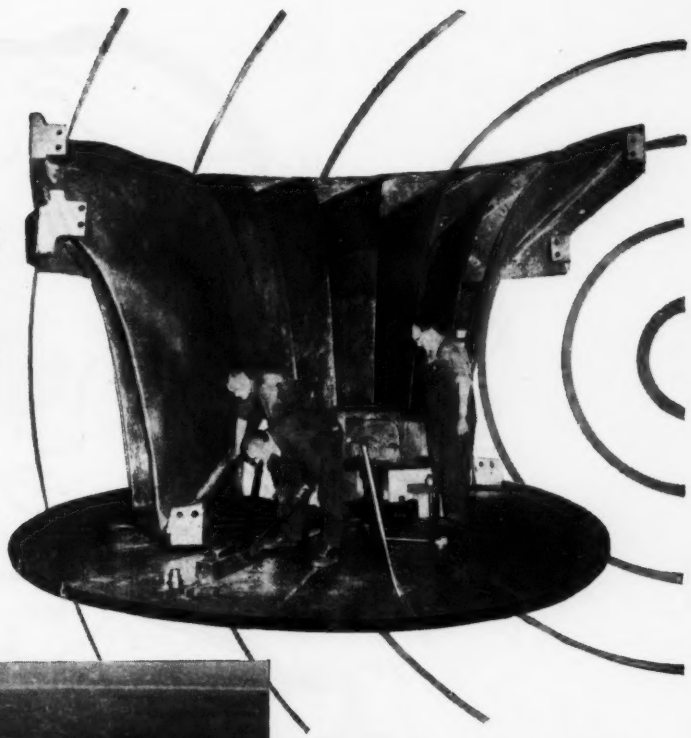

On the St. Lawrence River, between Lake St. Francis and Lake St. Louis, a fifteen mile long canal three-quarters of a mile wide feeds the Beauharnois Power Plant of the Quebec Hydro Electric Commission.

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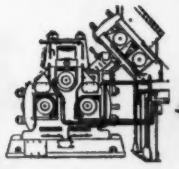
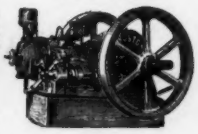
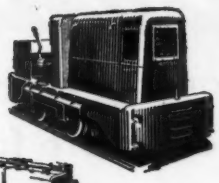


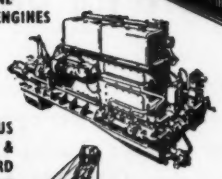
RUSTON HORIZONTAL OIL ENGINES



RUSTON DIESEL LOCOS

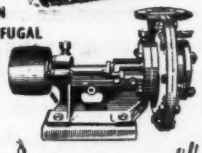


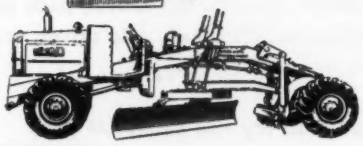
RUSTON MARINE OIL ENGINES



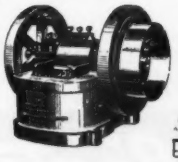
RUSTON-BUCYRUS EXCAVATORS & AVELING-BARFORD DIESEL SHUTTLE DUMPERS

RUSTON CENTRIFUGAL PUMPS





AVELING-AUSTIN '99-H' MOTOR GRADER



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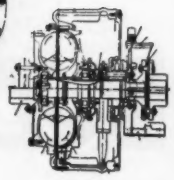
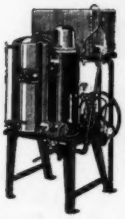


VULCAN-SINCLAIR FLUID COUPLING



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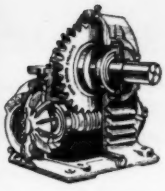

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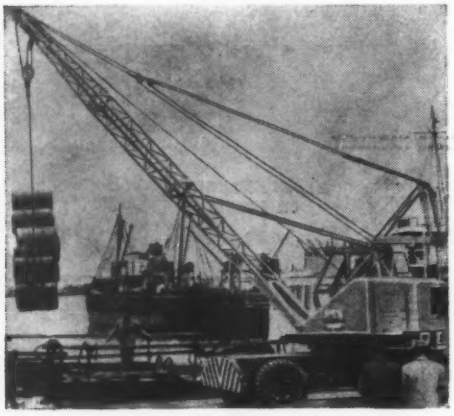

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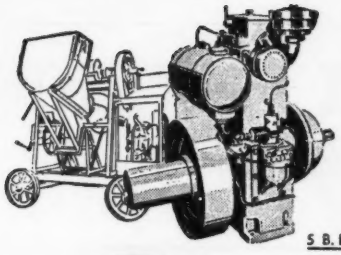

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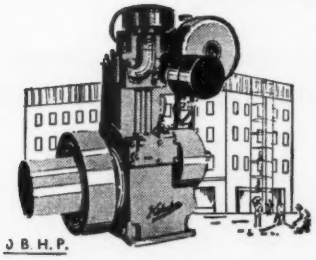

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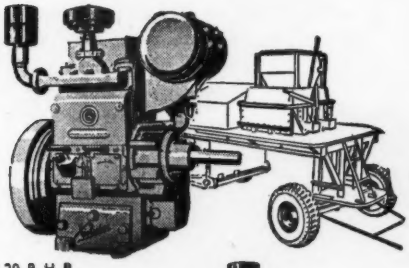

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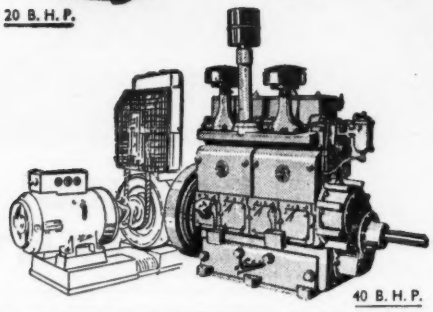

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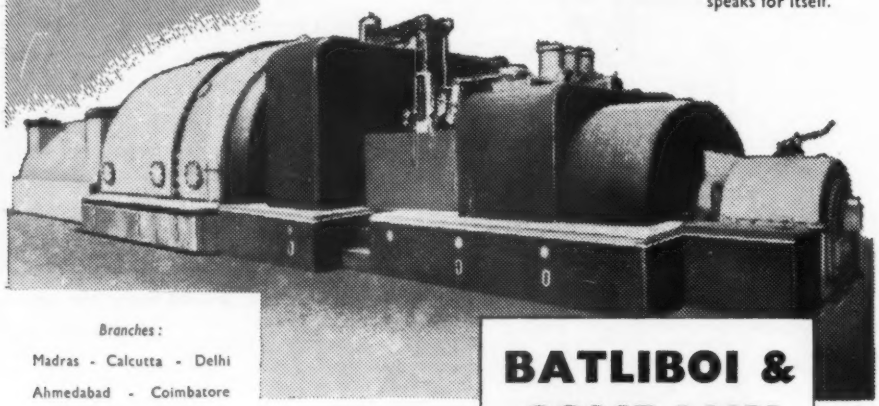

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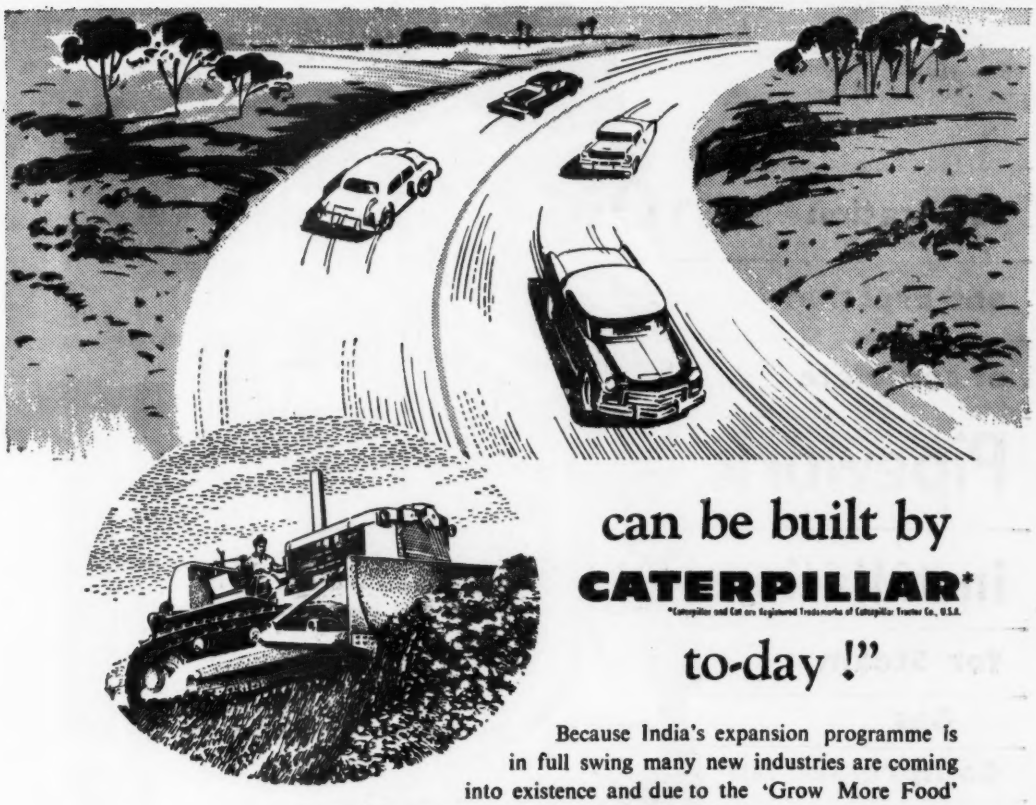

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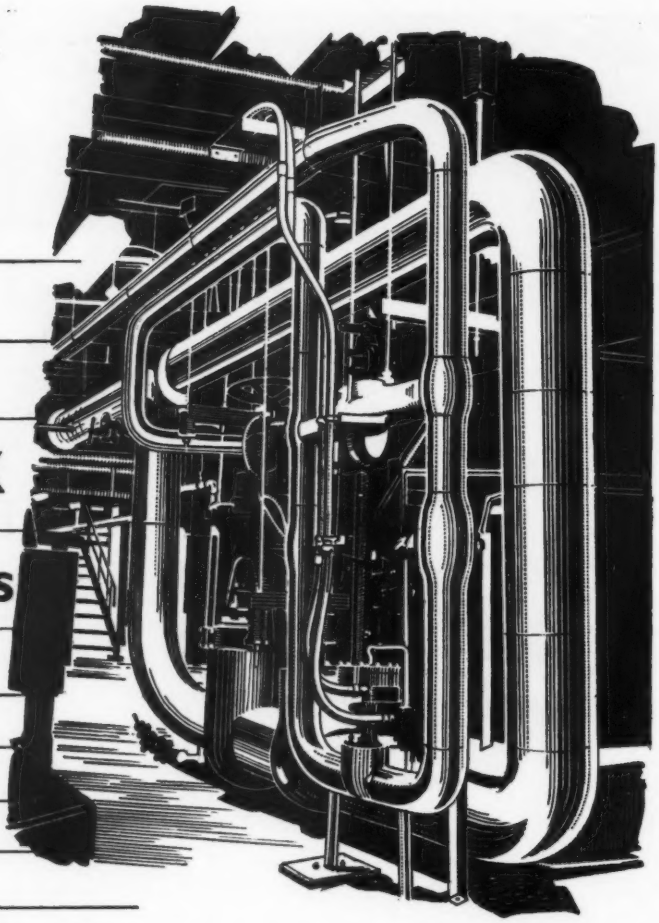

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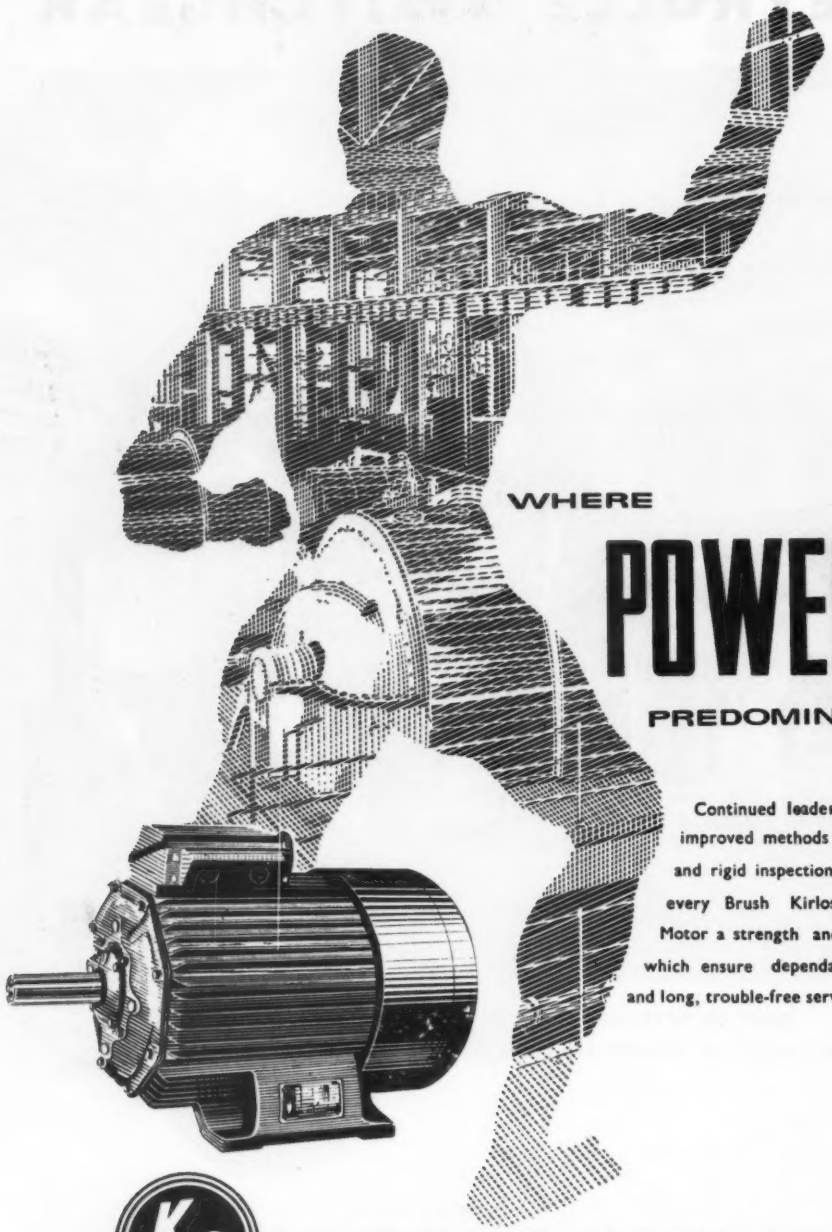

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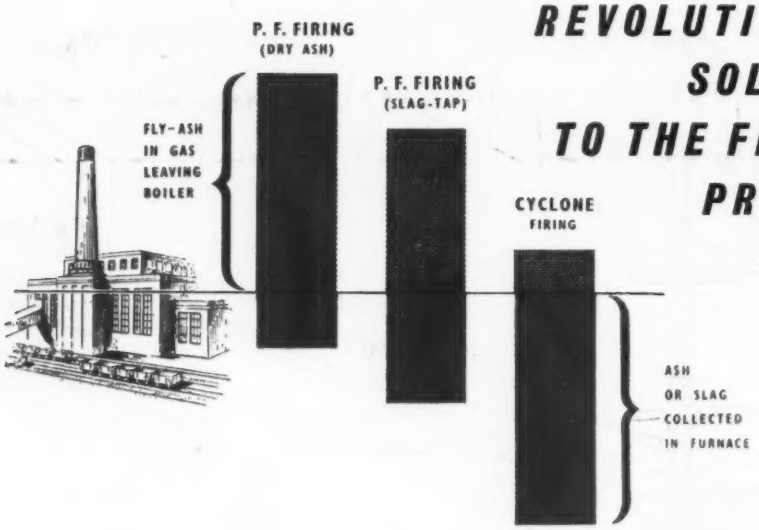

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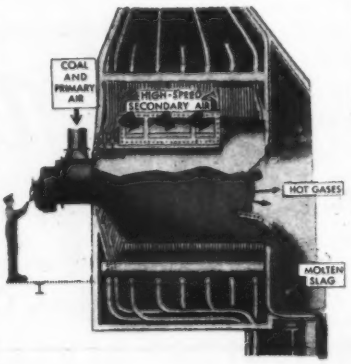
A Babcock development, the *Cyclone* furnace, after many years of research and full-scale service, is now established as one of the most effective methods of coal-firing power station and large industrial boilers, with these further important advantages :—

The coal is borne into the water-cooled refractory-lined furnace by a stream of high-velocity primary air and meets a tangential stream of high-velocity secondary air, forming a vortex of flame in which the fuel is completely burned, the hot gases passing into the boiler. The temperature in the *Cyclone* is high enough to liquefy the ash which clings to the walls forming a continuous coating of molten slag, which flows out of the furnace and is tapped into a water-filled tank.



Highest boiler efficiency due to efficient combustion, cleaner boiler surfaces, and lower power consumption for coal preparation—since the coal need only be crushed or coarsely pulverized.

Burns even poor grade, high-ash coals, at high combustion rates.

Due to high ash recovery and simpler ash disposal and coal preparation, removes various causes of heavy maintenance and shut-down ; so further improving boiler availability.

Enables greater evaporative capacity to be obtained in less total space. Smaller boilers, with less ash and dust-collecting plant and other auxiliaries, can be housed in less costly buildings.

Ideally suited to simple, automatic combustion control. Safe in operation. Easily started up. Ignition stable under all load conditions.

Flexible operation to meet wide load variations. Can be arranged for alternative firing with oil or gas.

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Drainage Study of Lower Damodar Valley—I

By SATYAKAM SEN, M.A.

The author has been engaged in hydrological studies of West Bengal rivers for the last five years. The present study is the outcome of research work as a special research student of the Government of West Bengal, in their River Research Institute, from 1954-'56 on the hydrographical features of the Lower Reach of Damodar. In his work he was helped by the D.V.C. with approach to some of their records. The present article constitutes the first part of a series.

Recognition of water as wealth to be utilised for progress of civilisation is not new. Civilisations of the past, for example, of the valleys of the Nile, the Euphrates, the Indus, the Ganges and the HwangHo flourished on the banks of those rivers. There is indeed no doubt that the human map may be said to follow principally the hydrographical map.

Utilisation of water drawn from various water sources to irrigate land is a very old practice in India. As we see, to-day also, to utilise an inch of land, water resources have got to be harnessed, and we find that every bit of available water source is being employed for human benefit by application of science. However, to make efficient application for such purpose, it is necessary to foregather all the geographical factors involved. Also, for persistence of the accruing benefits from such applications, it is necessary to continually note how these factors change when the water resources have been brought under human control with the aid of science. Importance of geographical survey of water resources for National Planning is therefore obvious.

Execution of the Damodar Valley Project has, since the achievement of independence of India, been a bold attempt to utilise the water resources of the eastern part of the country for all-round economic development.

Geographical Setting

The river Damodar rises from the Khamarpat Hills of the Chotanagpur plateau which is nearly 2000 feet high, and 336 miles long. It emerges into the Burdwan Plain below Raniganj, finally falling into the river Hooghly at Falta which is 30 miles below the city of Calcutta. The total catchment area covered by the Damodar Valley Project, is 9240 sq. miles. Of this the upper Damodar catchment, up to Rhondia, is 7,690 sq. miles and the lower reach below Rhondia is 1550 sq miles. The area that is covered by the present investigation, to be particular, the lower reach of Damodar, is situated between latitude 22°N an 24°N of equator and longitude 87°E and 88° 30′E of Greenwich.

The Problem

The D.V.C. area, important as it is, has become more so after the partition of the country, especially from the agricultural point of view. Since partition, West Bengal has been facing acute food shortage. The rise in population, which enhances pressure on land, as well as the decline in the productivity of the soil are obviously the causes leading to the agrarian crisis. D.V.C. dams should ameliorate this critical agricultural condition, as they would certainly improve the productivity of the soil in the lower reach of Damodar.

The river behaviour in the lower reach of Damodar, relating to proper utilisation of water, has been the subject matter for discussion in this text. The object of this investigation, as recorded in the following pages, is to study the hydrological conditions of Damodar in its lower reach, and also to evaluate the intricate problems of the river's behaviour. In the light of this study it is intended also to find out what repercussions are likely to occur in the area under investigation, after the D.V.C. dams have been completed and brought into operation.

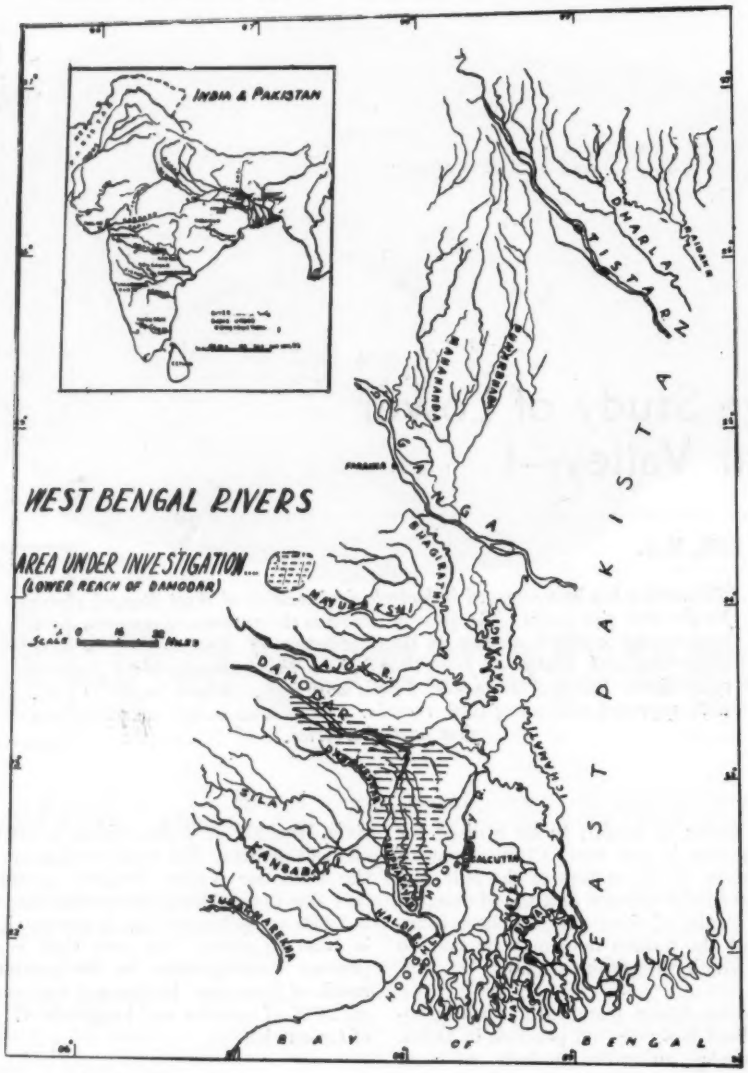

Fig. 1

Explanations of Fig. I, II & III

Fig. I—West Bengal is a land of rivers. The characteristic features are : the rivers to the North of Ganga are southflowing while the rivers to the west of Bhagirathi are eastflowing. River Damodar is an important member amongst the tributaries of Bhagirathi. Its flood discharge is high ; it is notorious for its destructing capacity ; and finally its floodplain has got capacity to provide for return of good harvest. Hence the study of the lower reach of Damodar (shaded portion) is important.

Fig. II—It shows that the River Damodar flows through Burdwan, Hooghly and Howrah District.

Fig. III—The drainage map of the lower reach of Damodar shows that the dense network of rivers lies much below Burdwan. The long continuous embankment is seen along the left bank of Damodar.

It starts from near Rhondia, and continues right upto the confluence of the Gaighata-Baxi canal with Damodar. The discontinuous right embankment is found below Damodar-Kaki confluence to run for a few miles. Forests are practically absent in the lower reach of Damodar, probably on account of the heavy demand for cultivable lands.

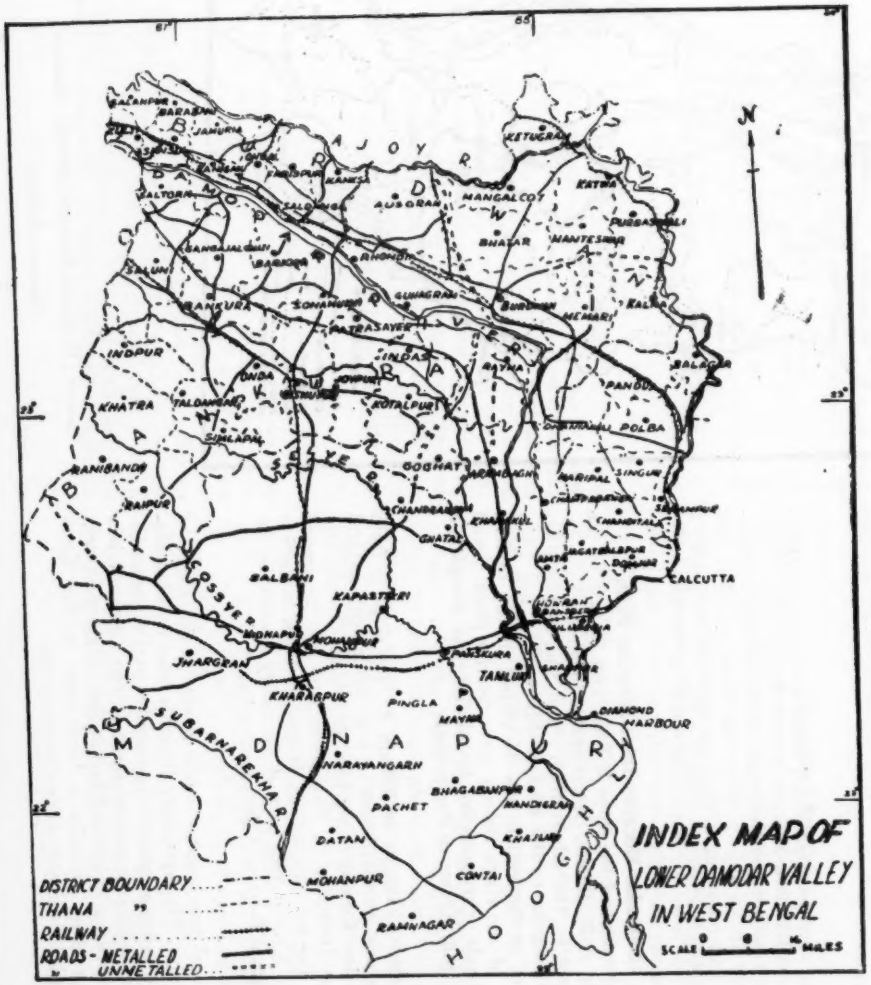
INDEX MAP OF
LOWER DAMODAR VALLEY
IN WEST BENGAL
DISTRICT BOUNDARY
THANA "
RAILWAY
ROADS - METALLED
UNMETALLED
SCALE
MILES
N
DAMODAR
AJOY R.
BARAKAR R.
KONAR R.
BARAKAR
KETUGRAM
MANGALCOT
KATWA
AUSGRAM
BHATAR
HANTESWAR
PURBASTHALI
KALNA
MEMARI
BURDWAN
GUSKARA
RANIGANJ
ASANSOL
JAMURIA
SALANPUR
BARABNI
KULTORI
SONAMUKHI
BANKURA
SONAMUKHI R.
PATRASAYER
INDPUR
INDAS
RAIPUR
PANDUA
BOLBA
KHATRA
TALDANGRA
ONDA
KOTALPUR
SIMLAPAL
BANKURA
DAMODAR
KASAI R.
KASAI
GOGHAT
MAHANAD
MAHISAL
SINGUR
CHANDRAKONA
GHATAL
KHANAKUL
BALARAMPUR
CALCUTTA
BALICHI
KAPASTERI
MOHANPUR
JHARGRAM
KHARAGPUR
PINGLA
MAYNA
TAMLUK
DIAMOND HARBOUR
SUBARNAREKHA R.
NARAYANGARH
BHAGABANPUR
HANDIERAM
PACHET
DATAN
KHAJURI
MOHANPUR
CONTAI
RAMNAGAR
HOOGHLY R.

Fig. 2

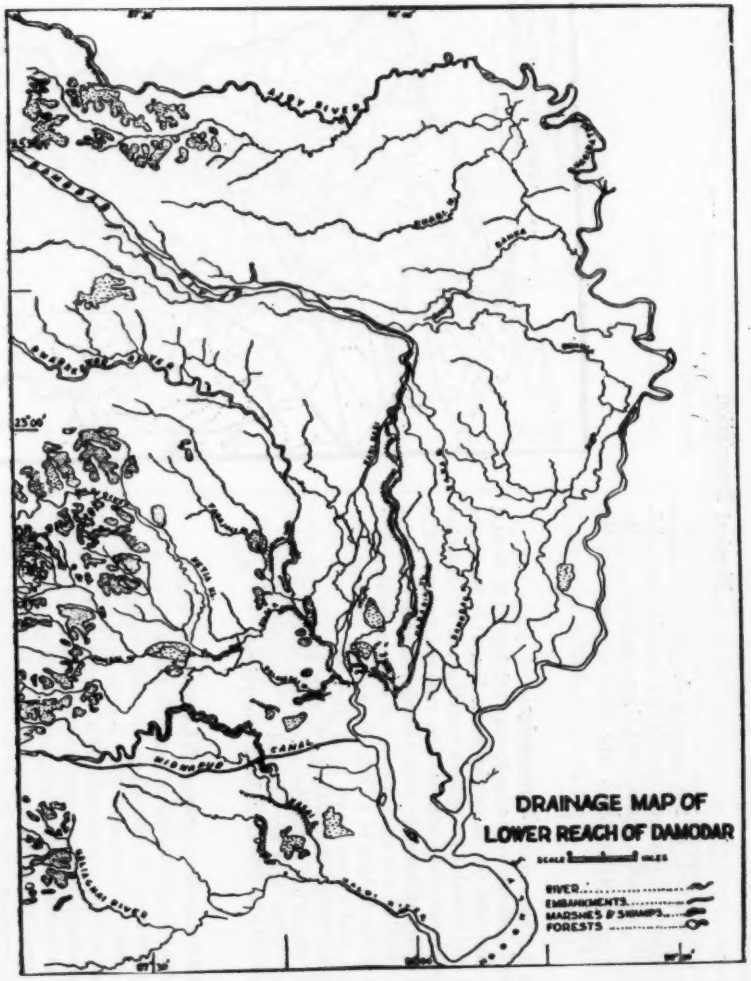
DRAINAGE MAP OF
LOWER REACH OF DAMODAR
SCALE
MILES
RIVER
EMBANKMENTS
MARSHES & SWAMPS
FORESTS
DAMODAR
HOOGHLY R.
KASAI R.
BARAKAR R.
KONAR R.
BARAKAR
BANKURA
BURDWAN
KALNA
PANDUA
BOLBA
SINGUR
CALCUTTA
KHARAGPUR
TAMLUK
DIAMOND HARBOUR
MIDNAPORE CANAL
HALDI R.
RUPNARAYAN R.
SALUKHAI R.
BELIAGHAI RIVER
25°00'

Fig. 3

Physical Description

It is intended, in the present chapter to examine the features of the lower reach of Damodar, especially the topography, the subsoil characteristics and the drainage channels which are vital elements in the landscape.

Topography

The 2 feet contour map for the left bank (fig. 5) and the 5 feet one for the right bank (fig. 4) in the lower reach of Damodar have been constructed to examine the detailed relief features. The regional trend of the slope is towards south-east. The elevation at Rhondia is 154 feet above mean sea-level while near Hooghly estuary the height is 4 feet. Numerous undulations, valleys and levees have been formed by the past behaviour of the channels. Low-lying pockets are also found, which are either occupied by marshes or water-logged areas and are devoid of cultivation. These regions help to breed malaria mosquitoes.

Damodar-Rupnarayan Inter-Riverine Plain

A close examination of contours reveals that the regional trend of the slope is from north-west to south-east. It appears like gentle steps, that is, somewhat like a staircase. The landscape seems to be one of alluvial rice terraces. The slope trend is from west to east to the north of Kata Khal and from north-west to south-east to the south of this khal. While crossing the Kana Nadi, the contours are more widely spaced than on the northern side of the river.

The average slope which exists between the Damodar and the Dwarakeswar is 2.1/2 ft. per mile. "This slope is rather less than that of the Damodar immediately above Jujuty where the slope is 2.83 ft. per mile and rather more than the slope between Jujuty and Edilpur where the slope is 1.55 ft. per mile." (1)

Damodar-Hooghly Inter-Riverine Plain

The trend of the slope is from west to east to the north of R. Banka. Innumerable meanders have developed in the Khari Nadi ; and the contours are very irregular to the west of this river. A low lying pocket or depression has developed in the eastern part of the Kaya-Behula inter-riverine plain. Small highlands or mounds are found along the Bhagirathi strip from Katwa to Purbasthali.

South of Gangur or Behula R., the slope is from north-west to south-east. A very prominent natural levee has formed along the left bank, downstream of the Damodar R. This levee can also be traced from the old channel of Damodar. Such formation of the levee in this part of the valley constitutes an important feature of the topography.

The slopes become more gentle to the south of Damador. The Saraswaty-Hooghly inter-riverine plain has become infested by marshes and depressions. The notable one among them is the Dankuni jala which is an area covered by marshes. Rajpur swamp, a depression, occupies a large tract in the Kana Damodar-Swarasaty inter-riverine plain.

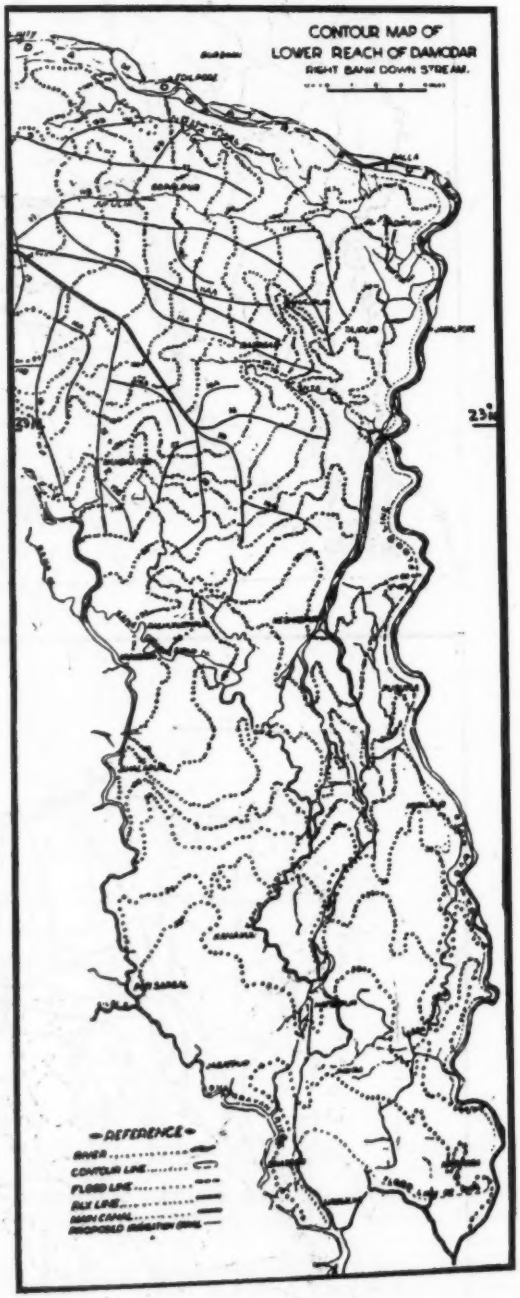

Fig. 4

Source : Damodar-Hooghly Scheme Contour Survey—1933-34.

Fig. 5
Source—Damodar-Hooghly Flushing Contour Survey—1933-34

Subsoil Features

The sub-soil of the area, up to the depth of 50′ (see table no. 1 prinedt separately), under investigation, has been sampled by bore-holes and has been divided according to international value of the particle size of the samples, as classified by Prescott and others (2). Clay, loam and sand predominate in the area. Nature of sedimentation as textural classification suggests, is either slow or quick, because coarse sand and clay deposition exist in most of the cases. Medium texture, i.e. silt plays a very minor part in the sedimentation in the Damodar-Bhagirathi inter-riverine plain.

Chemical Analysis of the Soil

Selected soil samples from bore-holes all over the area have been tested for pH and show that a large majority of soils at the top surface have pH ranging between 6.5 and 7.5 (fig. 6). Only in 2 places, Khrishnarampur and Puinan (Hooghly District), pH recorded is slightly higher. In the above 2 stations the salt present in the soil is also high (1.66% and 1.72%). The areas with high pH content and with high salt, present in the profile, are under the threat of a potential danger of alkalisation at a subsequent stage if conditions become favourable. It is interesting to note that, in all the stations, pH increases with the depth except at two or three places (Bajemalia-Hooghly District; Radhanagar and Gidhagram-Burdwan District). In these places, slight decrease of pH has been observed with increase of depth. There are a few stations where pH value remains more or less the same with increase of depth.

There are 10 stations where salt content is more than 0.100%. Out of these, in 4 stations, the salt present in the soil is above 0.150% (Krishnarampur, Puinan, Kotalpur-Hooghly District; Akalpaush-Burdwan District). The percentage of salt present in the soil is found to be greater in the Hooghly District than elsewhere.

Carbonate is by far the major chemical constituent present in the soil. In the upper surface, most of the stations show traces of carbonate, but in the middle and lower layers, carbonate is only sometimes present.

Damodar Group and Bhagirathi Group

Two distinct groups of sediment are evinced by colour. The colour of Damodar sand is brown or yellow. The colour of the Bhagirathi particles is grey. Soil profiles are drawn according to textural classifications which have been plotted for different depths, and then east-west and north-south grid lines (fig. 7) have been selected for the study of nature of subsoil geology in the area under investigations.

East-West Profiles

A close examination of the east-west subsoil profiles reveals the nature of sedimentation (fig. 8).

Diagram No. 1 shows that clay soil rests on sand. Particularly in Haridaspur, sand is available upto the depth of 45′ and the clay loam from the surface to the depth of 11′. The bottom sand is whitish yellow and the rest, of grey colour. In Dastanpur which is in the proximity of Damodar R., sand is found at the depth of 22′ to 25′, and below it, medium clay occurs. Above it, clay loam and medium clay are found. The colour of the clay soil is yellowish grey.

Digram No. 2 shows that in Brahmanpara, sand is found upto the depth of 15′ from the surface, and below it, heavy clay and silt loam occur. The colour of the sand is yellowish grey and grey. In Bajemelia, clay predominates in the subsoil. The sand of yellow colour appears at a depth lying between 9′ and 15′.

Diagram No. 3 reveals that clay soil predominates in the area concerned. Sand of yellow colour appears at a depth of 34′ to 35′ at Puinan, and between 37′ and 38′ at Bhanjipur which is situated near the Damodar river.

Diagram No. 4 shows that soil of coarser texture, that is, sand, is practically absent in both the profiles. Clay soil is found in either of them.

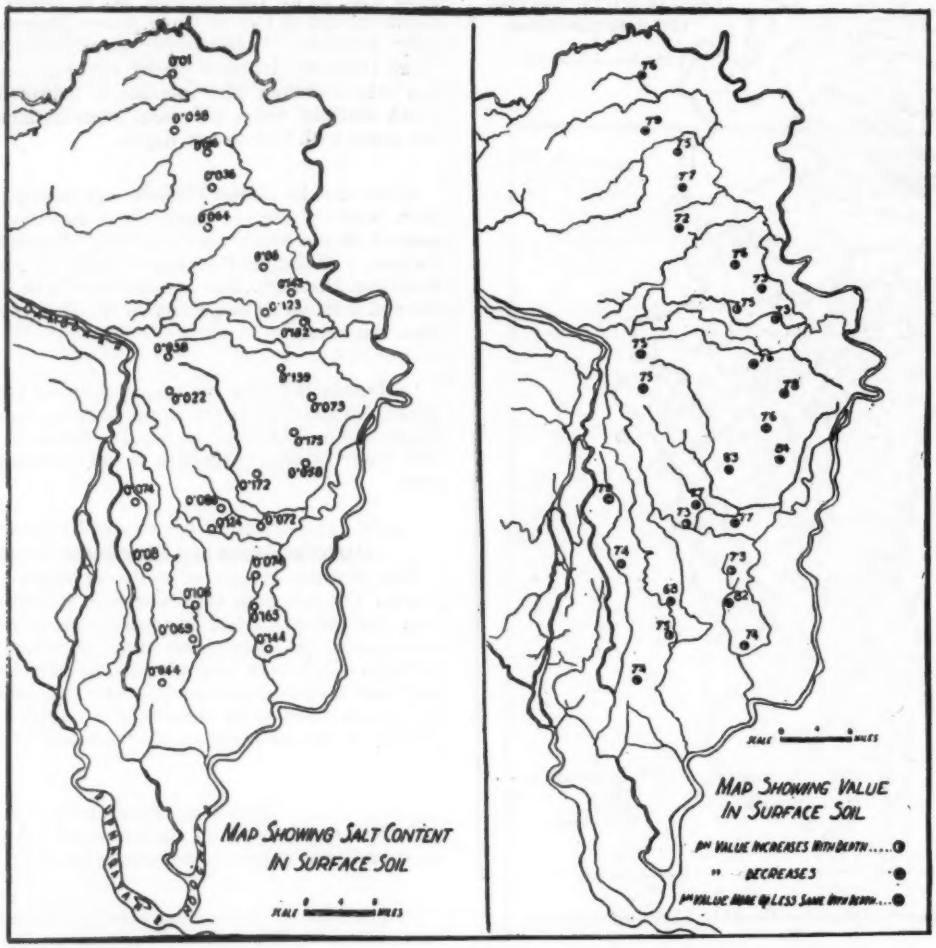

Fig. 6

North-South Profiles

A close examination of the north-south subsoil profiles reveals the longitudinal sedimentation of the area (fig. 8).

Diagram No. 5 shows that clay soil is found on the upper layers of the profie. Sand of yellow colour appears below clay at a depth of 37′ at Bhanjipur, and from 7′ to 21′ and 59′ to 60′ at Rajhati.

Diagram No. 6 shows that a fine soil texture, that is, clay and clay loam, is found on the upper sections of the profiles. Sand is found between the depths of of 20′ and 30′ from the surface at Gidhagram, Mahes-Danga and Dastanpur.

Diagram No. 7 shows that clay formation predominates in the subsoil geology. Sand is only found at Denur at a depth of 26′.

Diagram No. 8 shows that sand of yellowish grey colour appears at the surface at Sultanpur, at a depth of 33′ (yellow colour) at Punian and of 19′ at Bajemelia. Clay soil is present in the upper section of the profiles. At the surface it is found to occur at Puinan, Bajemelia, Gangadharpur and Krishnarampur. Heavy clay is found at Dakhinbari and medium clay at Begpur.

From Diargam No. 9 it can be seen that sand of yellow and grey colour occur at Radhanagar (10 to 15 ft. depth) and Haridaspur (below 26′ from the surface) ; otherwise clay and clay loam predominate.

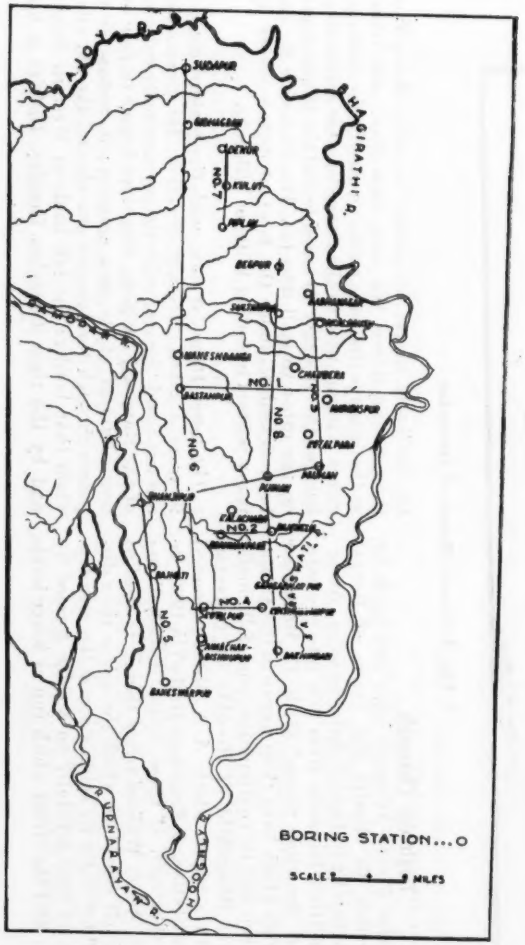
SUDHPUR
GIDHAGRAM
KOTALPUR
BEGPUR
BANESWARPUR
CHANDERA
DASTANPUR
PUNAN
BAJE MELIA
DENUR
KULUT
PIPLAN
BANESWARPUR
BHAGIRATHI R.
JALANGI R.
BORING STATION...O
SCALE 0 4 8 MILES

Fig. 7

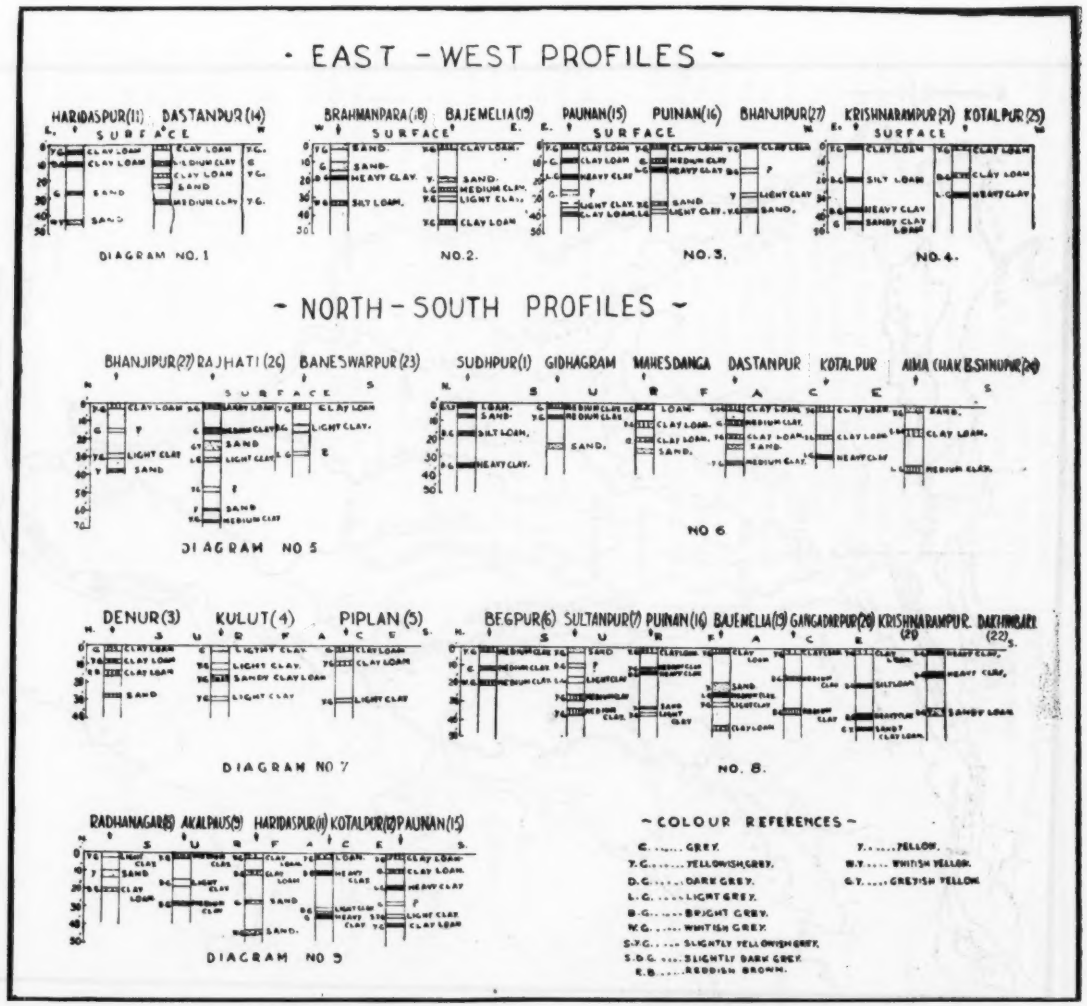
- EAST - WEST PROFILES -
HARIDASPUR(11) DASTANPUR(14)
BRAHMANPARA(18) BAJEMELIA(19)
PAUNAN(15) PUINAN(16) BHANJIPUR(27)
KRISHNARAMPUR(21) KOTALPUR(25)
SURFACE
DIAGRAM NO. 1
NO.2.
NO.3.
NO.4.
- NORTH - SOUTH PROFILES -
BHANJIPUR(27) RAJHATI (26) BANESWARPUR(23)
SUDHPUR(1) GIDHAGRAM MAHESDANGA DASTANPUR KOTALPUR AIMA CHAK B.SHNUPUR(24)
DIAGRAM NO 5
NO 6
DENUR(3) KULUT(4) PIPLAN (5)
BEGPUR(6) SULTANPUR(7) PUINAN(16) BAJEMELIA(19) GANGADHARPUR(20) KRISHNARAMPUR. DAKHINGARI (21) (22)
DIAGRAM NO 7
NO. 8.
RADHANAGAR(8) AKALPHUS(9) HARIDASPUR(11) KOTALPUR(12) PAUNAN(15)
DIAGRAM NO 9
- COLOUR REFERENCES -
G. ..... GREY.
Y. ..... YELLOW.
Y.G. ..... YELLOWISH GREY.
W.Y. .... WHITISH YELLOW.
D.G. ..... DARK GREY.
G.Y. .... GREYISH YELLOW.
L.G. ..... LIGHT GREY.
B.G. ..... BRIGHT GREY.
W.G. ..... WHITISH GREY.
S.Y.G. .... SLIGHTLY YELLOWISH GREY.
S.D.G. .... SLIGHTLY DARK GREY.
R.B. .... REDDISH BROWN.

Fig. 8

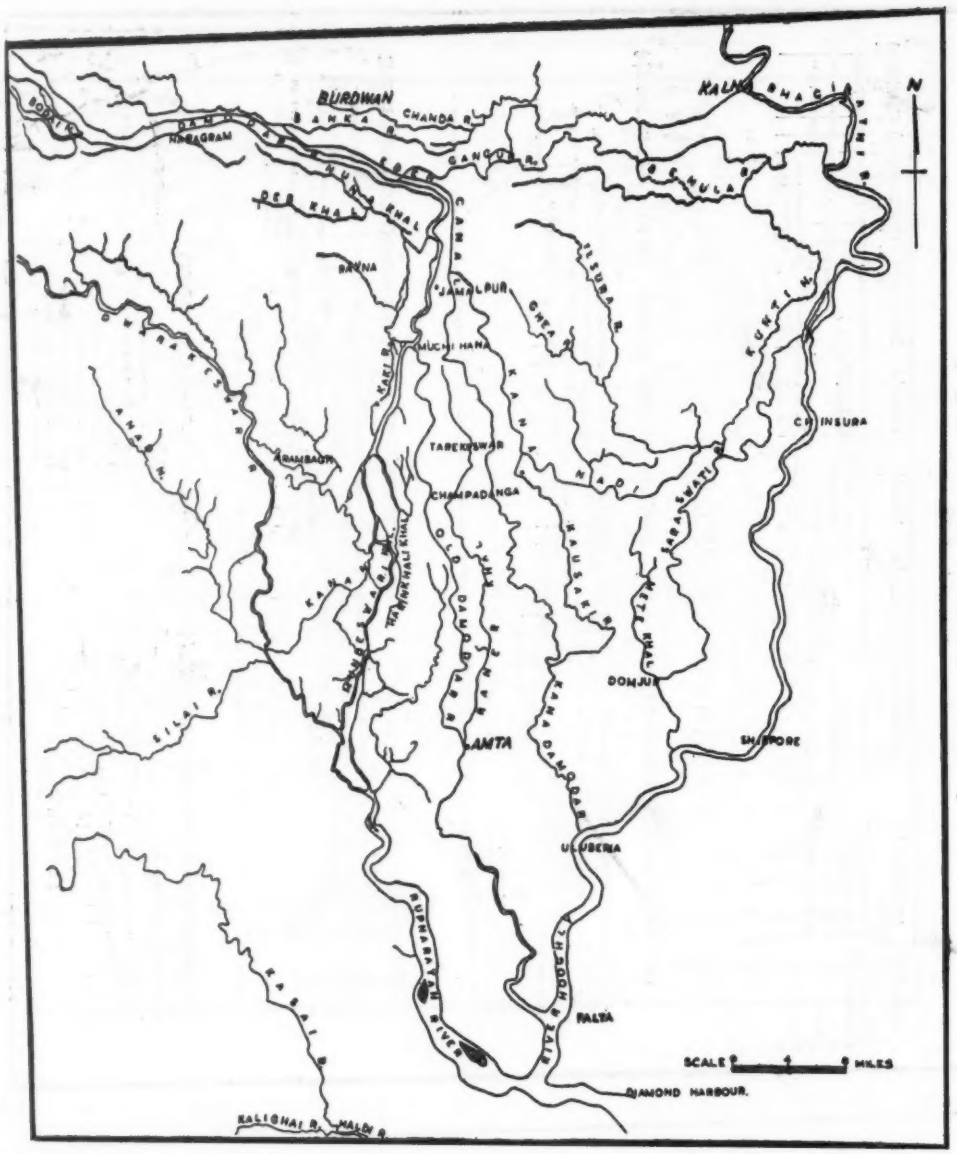

Fig. 9—Lower Reach of Damodar

Drainage Channels

The Damodar River—Attempts have been made by previous writers to classify the rivers of Bengal according to their hydrological characteristics. According to Major Hirst Damodar river falls into the category of 'land denuding rivers.' (3) S. C. Mazumdar terms the rivers which have their source in the Chotanagpur plateau and its continuation, and fall finally into the river Bhagirathi or Hooghly as 'torrential rivers' (4). In a paper which A. N. Mitra presented before the Institution of Engineers (India) in 1932, he pointed out that each of these active delta-building rivers (as Mr. Adam William terms them), is flanked by river on each side, into which the active river disposes of its flood-water by spilling across the country. An active river runs generally on a ridge formed by its own silt ; and the rivers which run at lower levels are evidently meant by nature to carry the spill of these active rivers. We may term these side rivers as the 'passive drainage rivers' or simply the drainage rivers. Coming now to the Damodar, this active river has got the Hooghly on one side and the Rupnarayan on the other to spill into (5). The Damodar R. has been described under the head of deltaic rivers by many writers including William Wilcocks.

The lower Damodar now, with the braided course, flows in a south-easternly direction. Its sinuousities are few ; and "leaving aside the permian sedimentaries of the Raniganj coalfield, this river begins to flow on new alluvium of its own creation ; it widens as it passes through the lateritic gravels and the old alluvium that borders the hill lands in Western Rahr ; and by the time it reaches Hooghly District it has

become a typical sluggish deltaic stream." The watershed line is not so perfect as the rain-catchment area "which is bounded in some districts by artificial features such as railway embankments or flood control 'bandhs' as the zone of subterranean infiltration during the dry season." (6) The left side of the river below Rhondia has got continuous embankment. But, on the other hand, the embankment on the right side was removed in 1863 to help the left embankment. The valley floor is wide at Rhondia and it continues over a few miles below Burdwan. Then at Palla a sharp bend in the river takes place, and the course which the river assumes is almost a southerly one. Concentration of water, right upto Jamalpur, is found sometimes to occur by the left bank and at others by the right bank, particularly whenever the river-bed contour is comparatively lower and the bed slope steeper, and in depression (e.g. Bishalakshi Dah—see Photo No. 2).

A map of the river Damodar published in 1857 by the Bengal Government (fig. 10) shows how the lower Damodar was an active river in the middle of the 19th century. But due to its avulsion into the drainage channel Mundeswari, in 1865, it has become a drainage river. There are also other drainage channels like Kabla Nadi, Harinakhal etc (See photo) but they do not have good quantity of flood water. Lower Damodar below Mohiddipur is not a very active channel today. A fraction of the normal flood discharge enters into the channel, the channel becoming constricted in form as it moves downwards. Amta onwards, the tides rule the lower Damodar.

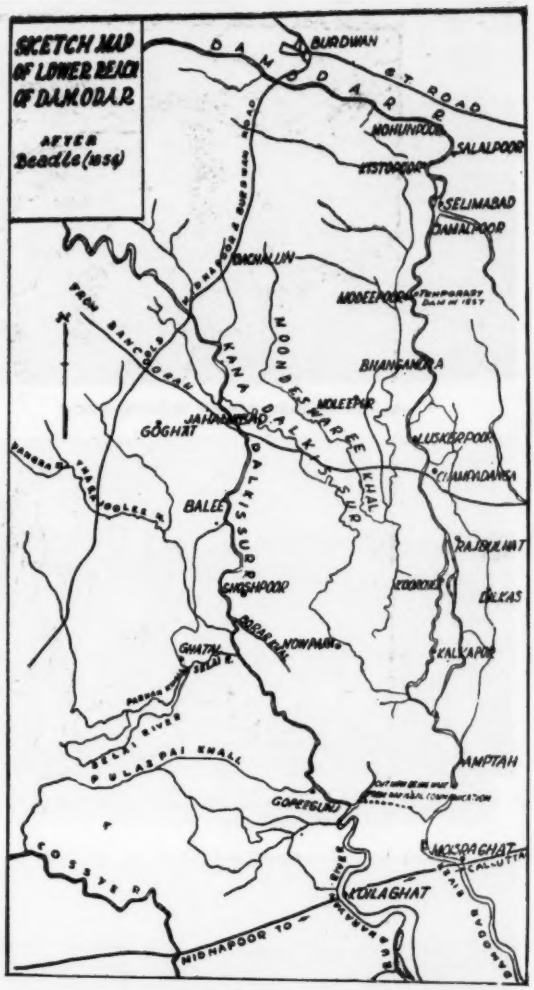

Fig. 10

Spill Channels—The whole, or at least a greater part, of the discharge brought down by the present Damodar R., diminishes by more than half from the bend at Salalpur, as we proceed upto Amta. The surplus floodwater partly gets spilled over the country (being consumed by hanas), and is partly discharged through other channels, such as the Banka, Kana Nadi, Kana Damodar and Madaria Khal on the left side, and the Mundeswari and Kana Dwarakeswar on the right. About 100 years back, the left side was completely closed to spill by a high continuous embankment, while the right side was lowered by the removal of 20 miles of old embankment. As a result of this the river overflowed the right bank annually for a distance of several miles till some years ago, when a great flood burst through the right bank at Begua. The flood water scoured through a long channel, flowing parallel to the main stream at a distance of about 2 miles, and finally swelled the volume conveyed by the Mundeswari, a drainage channel. The combined stream, after joining the Kana Dwarakeswar which is also known as the Kana Nadi, instead of coming eastward into the Damodar Khal, forced its way into the Rupnarayan opposite Ranichak. This combined stream runs wider and deeper, carrying a large influx of water into Rupnarayan in the flood season. As a result the main channel, lower Damodar, has shrunk perceptibly. The spill carries all the top water while the bottom water, with a full complement of coarse sand, moves along the lower Damodar river bed. With the removal of right embankment in 1863 the river secured the privilege of free spill over the right bank.

Left Bank Channels—There had been a number of spill channels on the left bank, that were blocked off by the left embankment. The old courses of some of these are still visible, and even found to be working as drainage channels. They are described here.

Gangur or Behula—It rises in the Burdwan District, and bifurcates into two channels near Baddipur. The northern branch of Gangur or Behula moves in a circuitous course, and meets the Hooghly water near Somra. The southern branch flows in a southeasterly direction and falls into Mogra Khal.

Nayaserai Branches—These are the old channels of Damodar which used to find their way into the Hooghly R. at and about Nayaserai, 3 miles above Tribeni.

Kunti or Kana Nadi—The Kana Nadi branches off from the main stream of Damodar near Jamalpur. It falls into Hooghly R. after taking semi-circular turn. The total length of the stream altogether is about 50 miles. The upper reach is annually flushed from Eden Canal. The channel has some flow of water all the year round.

Photo No. 1. Damodar R. at Durgapur

Photo No. 2. Bishalakhi Dah

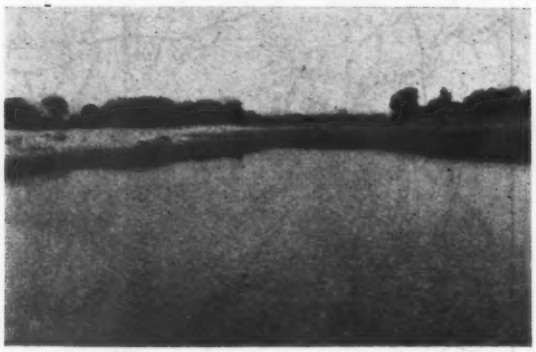

Photo No. 3. Main Damodar Down-Stream below Mohiddipur

Photo No. 4. Mouth of Begua Hana and Main Damodar

Photo No. 5. Mouth of Begua Hana and Kaki River.

Photo No. 6. Mouth of Muchi Hana and Kaki River

Photo No. 7. Banka Nadi at Jhaunpur

Photo No. 8. Kana Damodar below Selimabad

Photo No. 9. Mundeswari River at Harinkhola

Photo No. 10. Harina Khal at Rautara

Photo No. 11. Kaki River

Photo No. 12. Damodar River at Champadanga

Photo No. 13. Damodar River at Jamalpur

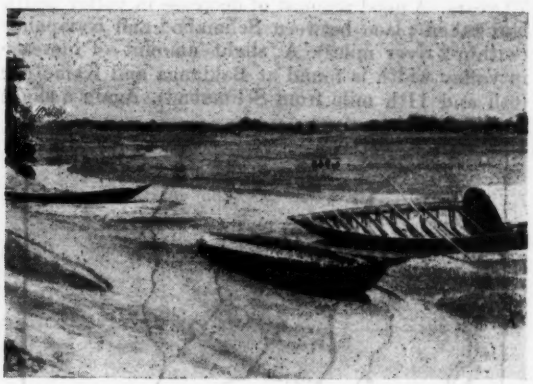

Photo No. 14. Damodar River at Amta

Kana Damodar—It was once a large channel. The mouth of the Kana Damodar has been silted up, and this channel is being flushed annually from the waters of the Eden Canal. Kausiki R. links up with the Kunti or Kana Nadi, and the Kana Damodar. Thereafter the combined stream flows on and finally falls into Hooghly R.

Khari, Banka and Brahmani Drainage Channels

Khari, Banka and Brahmani and also other intermittent streams have escaped the influence of spilling due to the Damodar left bank embankment. Vanden Brouke's map (1660) depicts that the Banka R. was a large one, and carried considerable quantity of discharge of the Damodar water. M. Peron's map (1780) of inland navigation shows that the Banka was navigable river for a considerable part of the year. Recent field survey (1956) represents Banka as a trifling stream (See Photo No. 7), having dry sandy bed as the prevalent feature in its upper reach.

The behaviour of these streams differs appreciably from that of the spill channels, and their life-cycle has been disturbed by the construction of embankments on the left bank of Damodar downstream. Naturally they are known as 'Beheaded Streams' (7). Some writers believe that "certain amount of entrenching of the river beds of the Khari and Banka to the east of Burdwan points towards the possible proof of elevation of this area. Moreover, the existence of terraces on the riversides, especially in the Khari, leads to the same conclusion" (8). Incised meanders cutting across the alluvial country with vertical cliffs, have been developed in the upper and the middle reaches of their basin. Perfect meanders have been developed in the consequent streams; these meanders happen across low lying areas or depressions or marshy tracts in their lower reach.

Width of the River Valley

The width of the Damodar river valley, in its lower reach, has increased considerably. By studying the increasing width of a rivervalley, one can of course measure the gradual extent of the floodplain in relation to time.

The present data also give an idea about lateral encroachment of the flood plain (see table no. 2). Considerable increase of the width in the Damodar R. has taken place at Raghabpur, Jujuty, Manikhati and Dhapdhara. Decrease of width occurs at Edilpur, Bacherhat and Serangpur. The width remains more or less constant at Palla, Salalpur, and Jamalpur. Only slight variations occur in these regions.

Change of valley width from bank to bank of Kana Nadi (between 1856 and 1933, i.e. 79 years) is shown in the table No. 3. In 1856 Kana Nadi possessed the symptom of an inundating river. Near Selimabad the width which in 1856 was 900 ft., became 134 ft. in 1933. The decrease of 766 ft. had taken place in 79 years. A good amount of decrease in valley width had taken place between Selimabad and Kalapahar (within 2 river miles). A slight amount of increase in valley width is found at Baldanga and Kamalpur (6th and 11th mile from Selimabad). Again a slight amount of decrease in valley width is found at Jadubatti (14.1/2 miles below Selimabad).

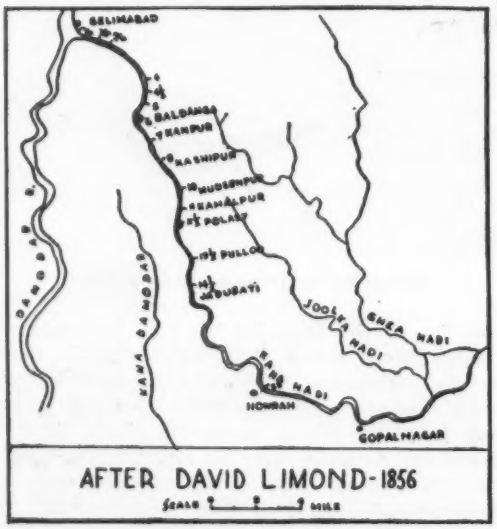

Fig. 11

A considerable amount of the decrease of flood plain in the upper portion was probably due to the decrease in the quantity of flood water and the consequent encroaching nature of cultivation on the widened fertile flood plains.

Rise of the River-Bed

The study of cross-sections recorded from 1888 onwards, reveals that the rate of aggradation has not been very unusual. However the study of the cross-sections of the 1913 and the 1943 flood-levels shows that there has been some progressive rise in the river-bed (See fig. nos. 12 and 13). The cross-sections of the Damodar channel at Raniganj is also almost steady. Scour and increase of river-bed go on simultaneously at Edilpur. Here, erosive action of the river is prominent. Cross-sections at Sarangpur, Manikhati, Palla, Jamalpur and Dhapdhara reveal that a rise of the river-bed has taken place on the whole, while scour sometimes occurs on the right bank side. At Champadanga the present river-bed (1955) is considerably higher than what the bed plane was in 1888, particularly on the right bank side. Slight scour has of course taken place on the left bank side. The present gutter-channel is the scoured portion over what it was in 1888.

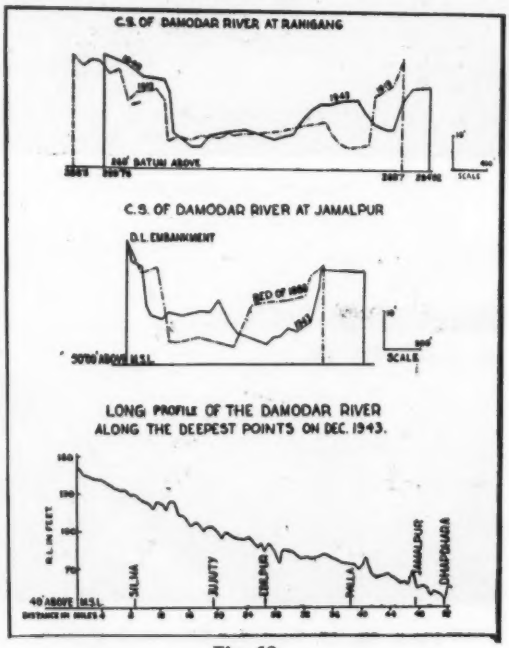

Fig. 12
Source: River Research Institute.

In 1929, the river-bed at Amta (fig. 14) was sufficiently deep. Considerable rise of river-bed took place from 1929 to 1949, particularly on right bank side. Left bank was scoured in 1934, and since then there has been a tendency to erode the left bank side because higher velocity as well as a directed bank-ward flow of flood water occur on that side. Superimposed cross-sections show that aggradation is the predominent feature in the river-bed.

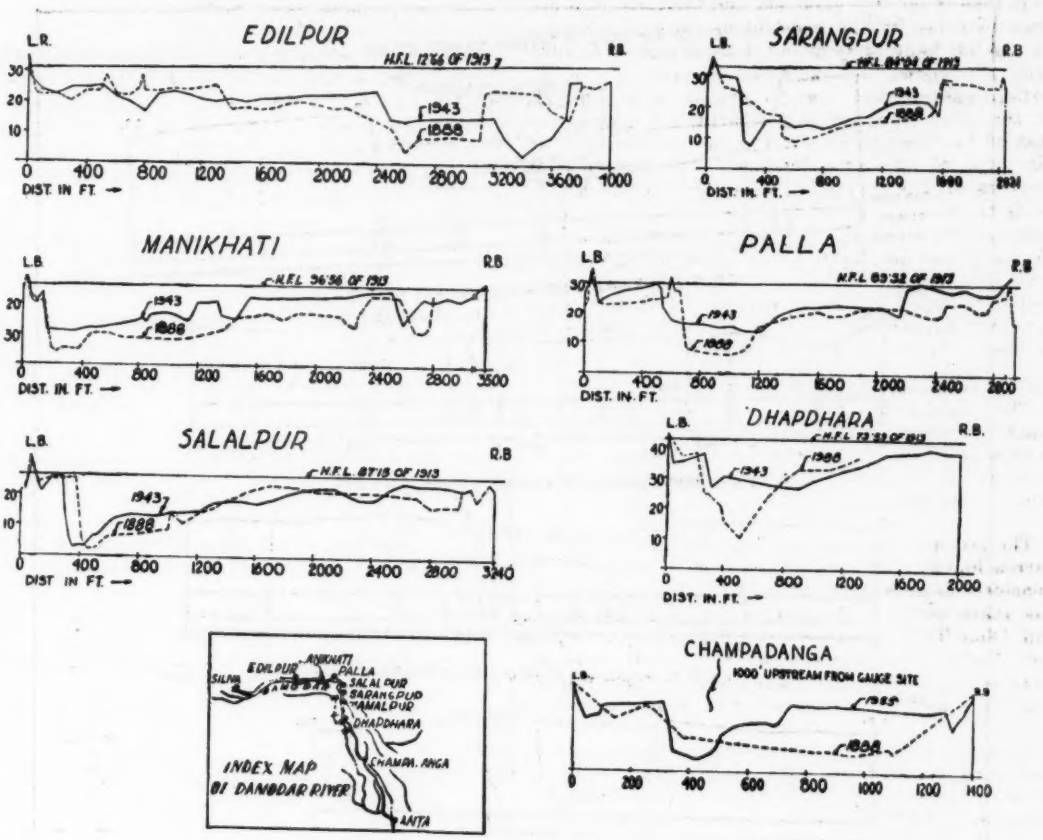

Fig. 13

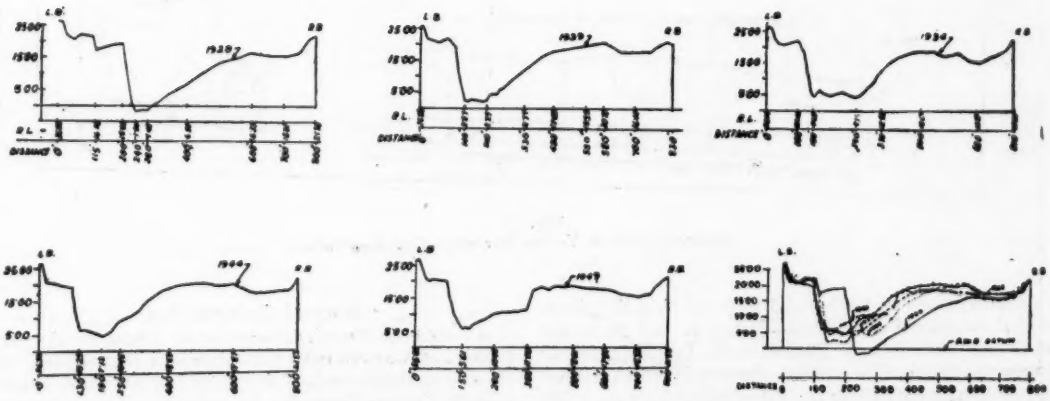

Fig. 14

Source—River Research Institute, West Bengal.

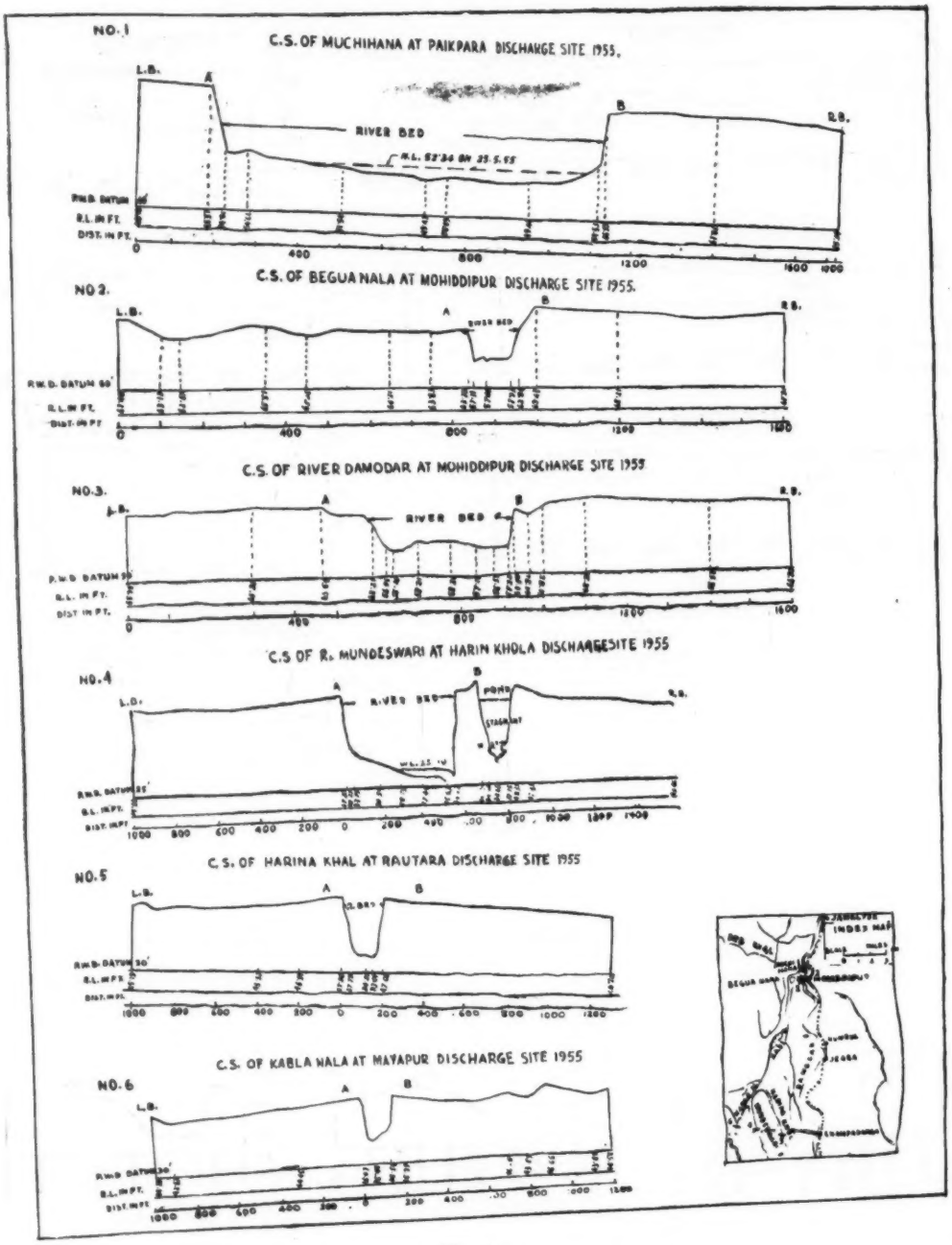

Fig. 15
Source—Lower Valley Investigation Committee

Cross-sections of 1955 (fig. 15) reveal that the river-bed is considerably wide at Paikpara, but narrower at Begua Nallah and Damodar R. (at Mohiddipur Discharge Site). The gutter channel is much deeper and wider at Mundeswari (Harinkhola) than what either the Harina Khal (Rautara) or the Kabla Nadi (Mayapur) happens to be. Comparatively large volume of flood water passes through Mundeswari, and this flowing water has got sufficient velocity to corrade the bottom.

Slope of the River-Bed

A long profile of the Damodar R. along the deepest points, as in 1943 between Silna and Dhapdhara, indicates that the bed of the river has not risen relatively to the neighbouring countryside, as it has been believed to have done by several experts (See fig. 12). It also indicates that the profile is not very smooth at the deepest points. The river-bed slope is gentle from Damodar Bridge site to Surekalna, just above the bifurcation point. Along Muchihana and Kaki

TABLE NO. 1

Statement showing Soil Texture, Mechanical and Chemical analysis of the Soil

Results obtained from : Central Testing Laboratory (D.V.C.) Maithon: The classification of texture was carried out by the author on the lines indicated by Prescott *et al* (2)

N.B. Coarse Sand: 2mm—0.2mm
Fine Sand —0.2 mm—0.02
Silt—0.02 mm: 0.002
Clay: <0.002mm.

Site No Sample No	*Mouza, PS & Dist. (in several order)*	*Soil Depth of Collected Sample*	*Texture of Soil*	*Result of Analysis*							
				Mechanical					*Chemical*		
				Gravel	*Coarse Sand*	*Fine Sand*	*Silt*	*Clay*	*Total Salts*	*pH*	*Carbonate*
1/1		0′ 0″-3′ 0″	Loam	0.4	7.1	46.5	25.6	18.4	0.01	7.6	Nil
1/2	Sudhpur,	6′ 11″-8′ 5″	Sand	0.4	40.8	54.7	0.9	2.8		7.9	Nil
1/3	Katwa	16′ 0″-18″ 4″	Silt loam	—	3.9	18.1	51.3	20.8		8.4	Trace
1/4	Burdwan	33′ 3″-36 4″	Heavy Clay	—	2.9	9.1	21.6	62.8		7.5	Nil
2/1	Gidhagram	0′ 0″-3′ 0″	Medium Clay	0.5	10.9	19.6	22,7	39.5	0.058	7.9	Present
2/2	Katwa	6′ 8″-8′ 10″	Medium Clay	0.7	6.7	24.4	19.9	46.0		7.5	Nil
2/3	Burdwan	22′ 0″-25′ 1″	Sand	10.2	75.9	6.3	0.9	6.3		6.9	Nil
3/1		0′ 0″-3′ 0″	Clay loam	0.1	17.1	27.5	27.0	23.0	0.016	7.5	Nil
3/2	Denur	7′5″-9′ 7″	Clay loam	5.0	31.7	15.8	13.6	31.3		7.8	Nil
3/3	Monteswar	13′ 6″-16′2″	Clay loam	0.2	39.5	19.4	13.2	26.2		7.1	Nil
3/4	Burdwan	26′ 5″-28′3″	Sand	1.5	65.0	21.8	1.6	9.1		7.1	Nil
4/1		0′ 0″-3′0″	Light Clay	0.3	5.4	27.6	25.2	40.0	0.036	7.7	Nil
4/2	Kulut	3′ 3″-13′ 6″	Light Clay	0.9	9.3	27.8	20.3	36.3		8.4	Present
4/3	Monteswar	16′ 2″-19′ 10″	Sandy Clay loam	—	31.4	36.7	6.5	22.3		7.1	Nil
4/4	Burdwan	28′ 2″-30′ 3″	Light Clay	0.2	2.7	21.8	31.4	37.8		7.5	Nil
5/1	Piplan	0′ 0″-3′ 0″	Clay loam	0.6	5.4	31.5	33.4	23.2	0.064	7.2	Nil
5/2	Monteswar	8′10″-10′ 10″	Clay loam	4.1	10.0	30.9	33.3	17.0		7.5	Present
5/3	Burdwan	29′ 11″-31′ 1″	Light Clay	0.6	7.3	27.2	23.2	33.1		7.5	Nil
6/1	Begpur	0′ 0″-3′ 0″	Medium Clay	0.2	0.6	11.7	41.7	42.0	0.06	7.6	Trace
6/2	Kalna	10′ 10″-13″ 3″	Medium Clay	0.4	6.0	18.9	25.9	42.1		8.0	Present
6/3	Burdwan	19′ 8″-21′ 4″	Medium Clay	1.1	7.1	21.4	21.6	42.7		8.2	Present
7/1		0′ 0″-3′ 0″	Sand	—	32.8	59.7	0.4	4.9	0.123	7.5	Nil
7/2	Sultanpur	9′ 4″-11′ 4″		—	1.0	12.2	39.4	34.6		7.1	Nil
7/3	Kalna	16′ 11″-20′ 4″	Light Clay	—	3.6	21.8	30.9	35.1		7.1	Trace
7/4	Burdwan	26′ 8″-29′ 11″	Medium Clay	1.6	4.5	19.8	24.2	42.5		8.5	Present
7/5		34′ 8″-37′ 10″	Medium Clay	—	12.5	15.4	26.3	39.8		7.8	Trace
8/1	Radhanagar	0′ 0″ - 3′ 0″	Light Clay	—	2.6	35.1	19.3	37.4	0.142	7.3	Nil
8/2	Kalna	10′ 0″ -14′ 0″	Sand	—	19.1	76.7	2.1	1.2		7.0	Nil
8/3	Burdwan	20′ 8″ -22′ 7″	Clay loam	—	24.1	21.6	15.9	33.5		6.8	Trace
9/1	Akalpaush	0′ 0″ - 3′ 0″	Medium Clay	—	1.6	20.2	29.7	41.3	0.182	7.3	Nil
9/2	Kalna	14′ 7″ -18′ 6″	Light Clay	—	1.2	22.2	31.6	35.7		7.5	Nil
9/3	Burdwan	26′10″ -27′ 6″	Medium Clay	—	3.3	25.6	21.0	45.2		8.4	Present
10/1	Chaubera	0′ 0″ - 3′ 0″	Silt loam	—	4.4	24.5	43.7	21.8	0.139	7.6	Trace
10/2	Pandua	10′ 6″ -12′ 5″	Clay loam	—	6.8	43.8	19.6	26.6		7.7	Nil
10/3	Hooghly	13′ 9″ -18′ 0″	Medium Clay	—	1.0	19.6	33.8	39.4		5.7	Nil
10/4		34′ 8″ -37′ 0″	Medium Clay	—	1.6	12.0	34.0	46.8		7.3	Trace
11/1	Haridaspur	0′ 0″ - 3′ 0″	Clay loam	0.3	1.8	40.6	27.6	26.6	0.073	7.8	Present
11/2	Pandua	9′ 9″ -11′ 8″	Clay loam	—	4.0	45.0	20.2	25.0		7.5	Nil
11/3	Hooghly	26′ 0″ -27′ 8″	Sand	0.2	32.0	62.0	0.5	2.5		7.8	Nil
11/4		42′ 6″ -45′ 2″	Sand	1.6 (4.76-2.0 mm)	91.4	3.6	2.2	0.3		7.7	Nil
12/1	Kataplur Mahanad	0′ 0″ - 3′ 0″	Loam	1.4	1.6	35.1	41.9	14.0	0.175	7.6	Nil
12/2	Polda	9′ 8″ -11′ 5″	Heavy Clay	—	0.5	5.8	30.9	56.5		6.8	Trace
12/3	Hooghly	30′ 0″ -32′ 2″	Light Clay	0.2	9.9	27.8	20.7	35.5		7.4	Trace
12/4		33′ 6″ -35′ 9″									
13/1	Maheshdanga	0′ 0″ - 3′ 0″	Loam	—	1.7	63.2	18.2	14.7	0.038	7.5	Nil
13/2		9. 5″ -13′ 0″	Clay loam	—	5.8	49.1	18.3	22.2		7.1	Nil
13/3	Memari	23′ 3″ -25′ 8″	Clay loam	—	10.9	18.6	33.6	30.3		8.0	Present
13/4	Burdwan	34′11″ -37′ 8″	Sand	0.5	79.1	15.4	0.8	3.8		7.5	Nil
14/1	Dastanpur	0. 0″ - 3′ 0″	Clay loam	0.3	23.5	25.5	17.9	17.2	0.022	7.5	Nil
14/2	Jamalpur	8′ 8″ -11′ 9″	Medium Clay	0.2	20.2	14.0	18.8	41.7		7.4	Nil
14/3	Burdwan	16′ 4″ -18′ 3″	Clay loam	0.4	40.4	22.7	8.8	24.5		7.4	Nil
14/4		22′ 3″ -24′ 1″	Sand	4.6	78.5	8.5	2.7	4.6		7.4	Nil
14/5		31′ 2″ -33′ 5″	Medium Clay	0.3	16.0	19.2	18.2	39.6		7.7	Nil

TABLE NO. 1—*contd*

Site No Sample No	Mouza, PS & Dist. (in several order)	Soil Depth of Collected Sample	Texture of Soil	Result of Analysis							
				Mechanical					Chemical		
				Gravel	Coarse Sand	Fine Sand	Silt	Clay	Total Salts	pH	Carbonate
15/1		0′ 0″ - 3′ 0″	Clay loam	—	2.7	23.3	35.7	30.8	0.058	8.4	Not found
15/2	Paunan	8′ 6″ -10′ 6″	Clay loam	—	9.7	29.9	32.1	26.2		7.2	Not found
15/3	Polba	17′ 6″ -19′ 5″	Heavy Clay	—	0.9	8.7	28.1	54.0		7.7	Not found
15/4	Hooghly	26′ 9″ -28′ 9″	Light Clay	—	3.7	15.7	20.7	48.4		8.4	Present
15/5		33′ 7″ -35′ 2″	Clay loam	—	8.0	26.3	25.1	34.4		8.2	Present
15/6		38′ 5″ -39′ 9″	Clay loam	4.76—2 mm	7.9	20.5	19.1	30.9		9.0	Present
16/1	Puinan	0′ 0″ - 3′ 0″	Clay loam	—	2.8	45.3	22.2	25.3	0.172	8.3	Not found
16/2	Polba	11′ 1″ -13′ 8″	Medium Clay	—	1.6	15.9	31.6	43.3		7.1	Present
16/3	Hooghly	13′ 3″ -15′ 0″	Heavy Clay	—	1.6	13.5	28.3	51.0		6.8	Not found
16/4		33′ 0″ -34′ 1″	Sand	—	64.2	22.9	2.6	8.3		8.4	Present
16/5		36′10″ -38′ 3″	Light Clay	—	6.3	23.3	24.8	38.7		7.7	Present
17/1	Kalachara	0′ 0″ - 3′ 0″		—	5.4	21.7	27.5	34.0	0.086	7.7	Not found
17/2	Haripal	11′ 7″ -15′ 3″	Heavy Clay	—	1.5	17.2	19.8	53.2		7.1	Not found
17/3	Hooghly	18′ 1″ -20′ 2″	Medium Clay	7.3	4.7	16.0	18.7	46.5		8.2	Present
17/4		31′ 3″ -34′ 1″	Medium Clay	—	6.3	19.7	24.3	45.2		7.8	Present
18/1	Brahmanpara	0. 0″ - 3′ 0″	Sand	—	46.3	36.3	4.6	101.	0.124	7.3	Not found
18/2	Haripal	9′ 6″ -14′ 8″	Sand	—	92.8	5.0	0.1	1.7		7.8	Trace
18/3	Hooghly	18′ 0″ -19′ 5″	Heavy Clay	—	1.8	10.6	26.6	55.6		7.3	Present
18/4		32′11″ -34′ 0″	Silt loam	—	2.3	15.7	49.5	27.8		8.3	Trace
19/1		0′ 0″ - 3′ 0″	Clay loam	—	0.9	51.1	24.0	20.7	0.072	7.7	Not found
19/2	Bajemelia	19′ 0″ -24′11″	Sand	—	79.7	10.4	2.5	1.9		7.5	Not found
19/3	Singur	25′ 2″ -27′ 1″	Medium Clay	—	3.7	20.8	25.4	46.0		7.6	Not found
19/4	Hooghly	30′ 0″ -32′ 2″	Light Clay	—	4.3	32.6	20.2	37.4		7.5	Present
19/5		43′ 2″ -45′ 6″	Clay loam	—	1.2	30.7	39.3	24.2		7.7	Not found
19—	Bajemelia (*ii*)	14′ 4″ -16′ 3″	Clay loam	—	5.0	42.1	29.7	18.2		6.9	Nil
20/1	Gangadharpur	0′ 0″ - 3′ 0″	Clay loam	—	0.3	49.9	25.8	20.1	0.074	7.3	Not found
20/2	Chanditala	15′ 3″ -17′ 3″	Medium Clay	—	1.8	18.5	28.6	45.7		7.8	Not found
20/3	Hooghly	33′ 2″ -36′ 2″	Medium Clay	—	9.3	22.6	20.0	42.2		8.4	Present
21/1	Krishnarampur	0′ 0″ - 3′ 0″	Clay loam	—	1.2	55.5	13.8	26.5	0.165	8.0	Trace
21/2	Chanditala	19′ 7″ -21′ 3″	Silt loam	—	1.3	10.6	45.4	39.0		7.6	Present
21/3	Hooghly	35′11″ -38′ 3″	Heavy Clay	—	3.8	21.3	18.3	50.9		9.0	Present
21/4		43′ 4″ -44′ 9″	Sandy Clay loam	—	17.4	52.6	4.1	22.1		8.4	Not found
22/1	Dakhinbari	0′ 0″ - 3′ 0″	Heavy Clay	—	1.6	7.3	22.9	62.1	0.144	7.4	Nil
22/2	Domjoor	12′ 4″ -15′ 9″	Heavy Clay	0.2	8.9	5.7	25.7	53.6		6.9	Nil
22/3	Howrah	32′11″ -36′ 8″	Sandy loam	0.2	1.8	66.8	15.4	12.0		8.4	Present
23/1	Baneswarpur	0′ - 3′	Clay loam	—	0.7	45.8	25.3	26.6	0.044		Trace
23/2	Amta	13′ - 17′	Light Clay	—	1.8	11.0	46.0	38.1		6.8	Present
23/3	Howrah	29′ - 30′		—	23.6	115.	22.8	21.5		8.3	Present
24/1	Aima Chak-Bishnupur	0′ 0″ - 3′ 0″	Sand	—	39.0	44.1	3.8	11.1	0.069	7.5	Nil
24/2	Jagatballavpur	12′ 7″ -17′ 2″	Clay loam	—	1.3	33.2	28.5	33.3		8.4	Trace
24/3	Howrah	33′11″ -37′ 1″	Medium Clay	—	8.3	14.3	24.6	46.7		8.4	Present
25/1	Kotalpur	0′ 0″ - 3′ 0″	Clay loam	—	3.6	36.8	23.2	32.0	0.106	6.8	Trace
25/2	Jangipara	16′ 8″ -18′ 5″	Clay loam	—	1.1	22.1	39.8	34.3		7.9	Present
25/3	Hooghly	27′ 1″ -29′ 5″	Heavy Clay	—	1.8	12.5	25.2	56.8		8.1	Present
26/1		0′ 0″ - 3′ 0″	Sandy loam	—	3.6	65.6	12.4	15.8	0.084	7.4	Not found
26/2	Rajhati	11′ 4″ -14′ 6″	Medium Clay	—	5.4	27.3	21.4	39.5		7.8	Trace
26/3	(P.O. At pur)	17′ 0″ -21′ 6″	Sand	—	44.0	39.2	4.9	10.7		8.0	Not found
26/4	Jangipara	26′ 7″ -27′ 4″	Light Clay	—	5.6	22.9	25.7	38.2		8.4	Present
26/5	Hooghly	47′ 2″ -49′ 6″		—	41.5	27.0	4.1	9.7		8.4	Present
26/6		59′ 3″ -60′ 2″	Sand	—	72.2	16.8	2.5	3.7		8.4	Not found
26/7		65′ 6″ -66′ 4″	Medium Clay	—	13.2	18.5	17.9	41.8		8.2	Present
27/1	Bhanjipur	0′ 0″ - 3′ 0″	Clay loam	—	3.3	39.2	25.9	28.5	0.074	7.9	Nil
27/2	Tarakeswor	14′ 8″ -16′ 0″		—	6.3	18.1	21.8	43.3		8.4	Present
27/3	Hooghly	27′ 9″ -30′ 9″	Light Clay	—	19.0	19.0	15.5	37.5		8.3	Present
27/4		37′ 2″ -38′ 0″	Sand	—	80.4	10.6	1.0	2.9		7.9	Not found

TABLE NO. 2

Statement showing the width of the Damodar R. in different Years

Stations	*Width of Rivers in feet during years*			
	1888	1913	1918	1943
Raghabpore	3600	6800	6800	6320
Jujuty	3240	4260	4300	5000
Edilpur	4100	4086	4086	3700
Bacherhat	4025	4150	4200	3650
Manikhati	2800	2800	2740	3230
Salalpur	3240	3170	3240	3020
Palla	2945	2895	2945	2930
Serangpur	2020	2040	2040	1650
Jamalpur	1300	1133	1133	1324
Dhapdhara	1300	1260	1300	1200

The data upto 1918 were obtained from Addams Williams Letter No. 7652 dated 20.9.18 ; The data for 1943 were collected from Damodar Flood Enquiry Report.

TABLE NO. 3

Comparative study of the Valley-width of Kana Nadi

Village	*Distance (miles*	1856 *Width data from Survey*[1] *(ft)*	1935 *Width data from Survey*[2] *(ft)*	*Increase (+) or Decrease(—) in 79 years*
Selimabad	0	900	134	—766
Selimabad	¼	286	103	—183
Paratal	1.½	519	125	—394
Kalapahar	1.¾	311	134	—177
Kanjata	4	175		
Kanjata	4.¼	220	220	
Joorool	5	314		
Baldanga	6	310	350	+ 40
Kanpur	7	240		
Kashipur	8	160		
Mudsunpur	10	210		
Kamalpur	11	230	268	+ 38
Palasy	11.¼	180		
Pulloo	13.½	150		
Jadubatti	14.¼	135		
Howrah	23	130		
Gopalnagar	....	....	146	

(1) After David Limond (2) After Mansingh

TABLE NO. 4

Statement Showing River-Bed Slope

Station	Av. Bed Elevation above M.S.L.	Drop between Stations (in ft).	Distance (River-miles)	River-Bed Slope	
				Ft/mile	Slope
Along the Damodar R.					
Damodar Bridge Site	285.00	93.0	30	3.10	0.00660
Durgapur	192.00	38.0	15	2.53	0.00050
Rhondia	154.00	97.0	46	2.11	0.00040
Jamalpur	57.0	2.7	2.½	1.08	0.00020
Sure-Kalna	54.3	1.0	1.½	0.67	0.00013
Bifurcation of Kanki-lower Damodar	53.3				
Along Mundeswori & Kaki R.					
Bifurcation (B.P.)	53.3	1.6	½	3.20	0.00061
Paikpara	51.7	7.1	5.½	1.29	0.00024
6 miles D/S from B.P.	44.6	4.9	4	1.22	0.00023
10 miles D/S from B.P.	39.7				
Along Mundeswori R.					
10 miles D/S. from B.P.	39.7	9.6	3.½	2.74	0.00052
Harinkhola	30.1				
Along Damodar R. (after Bifurcation)					
Mohiddipur	57.4	25.5	13.½	1.88	0.00036
Champadanga	31.9	22.9	21.½	1.07	0.00020
Amta	9.0				

Compiled from "Data on Silt Analysis in the Damodar Basin (D.V.C., 1954) and Hydraulic Data—Field Division" (D.V.C. Maithon, 1955).

Nadi, the river-bed slope is slightly steeper from bifurcation point to 10 miles downstream (See table no. 4).

Drainage Density

The Drainage Density or D_d is the average length of stream per unit area within the basin, ie $D_d = \frac{\Sigma L}{A_d}$ while L is the total length of the stream and A_d is the drainage area (9). A value of drainage density above 5 miles/sq. mile is considered to represent a well-drained area. The Drainage Density of the Lower Reach of Damodar below Rhondia, is 0.41 miles/sq. mile. Therefore, the drainage of the area concerned is extremely poor and indicates long overland travel of surface water.

Inland Delta of Damodar

The question is often raised as to whether Damodar has formed a delta in the geographical sense of the term.

A deltaic region begins from the point where distributaties are given off. To be more precise the definition of delta would be "that portion of a riverine deposit demarcated on one side by the sea or lake in which the deposit is formed, and on all others by the distribution of the stream, its apex being at the point from which the splitting of the stream begins" (10). In this sense the Damodar delta (even if we call it so) is unlike the Ganges delta or the Nile Delta. The deltaic action of the Damodar is indeed entirely different. In the first place, the river has no sea-face though its outfall rivers, Hooghly and Rupnarayan, are subject to tides. The tidal action of the sea is not the factor responsible for the formation of the delta. Its deltaic action starts much higher up at a place where it can no longer carry the excess charge of sand that it brings down from the hills, and so drops it on the bed. This reduces the waterway considerably and the river breaks through its banks and debouches on to the plains through various channels giving rise to a deltaic form. Deltaic action of the Damodar begins with the recession of the river from the high banks on both sides, and as the slope of the country, through which the river flows, flattens.

The shape of the drainage lines taking deltaic form, and the tidal Hooghly acting as the sea-face, the delta built by the Damodar R. can be termed as 'Inland Delta'. This delta extends from its apex at Burdwan to Kalna on the North and to Geonkhali on the south. In the 17th Century the main flow used to pass into the northernmost course near Kalna, whereas the present flow regime confines to Rupnarayan.

The study of subsoil geology furnishes the following facts—

(1) There are no continuous layers of sand, silt or clay present in the inland delta of Damodar.

(2) The detritus brought down by the two rivers, Damodar and Bhagirathi, are found to be intermixed at all places. The boring stations close to Damodar (nos. 23 and 25) show Bhagirathi detritus, while stations (nos. 3 and 8) close to be Bhagirathi R. indicate the presence of Damodar sand.

(3) Scattered claypans of varying thicknessess are found to infiltrate beds of sand or silt over the deltaic region.

The above facts reveal that the two rivers, the Bhagirathi and the Damodar, and their spill channels have been wandering to this side and that, and intermixing during the past over the area, and have thus built up the inland delta.

Now with human interference the delta forming activities of the Damodar have been completely disturbed. The embankments on both banks of the river have stopped all spill, cutting off successfully the distributaries on the left bank such as Banka, Kana Nadi and others. Further human action has been pushing the river course more and more towards the right and has ultimately led the main channel into Mundeswari through which also flows the drainage of the Trans-Damodar area and the spill waters over the right bank starting from the Bibirhagan Hana. It can therefore be expected that with the reduced discharge that is likely to flow down the river in future due to D.V.C. dams, the river will form a stable channel below Begua Hana unless tidal action forces the river to break up into different channels.

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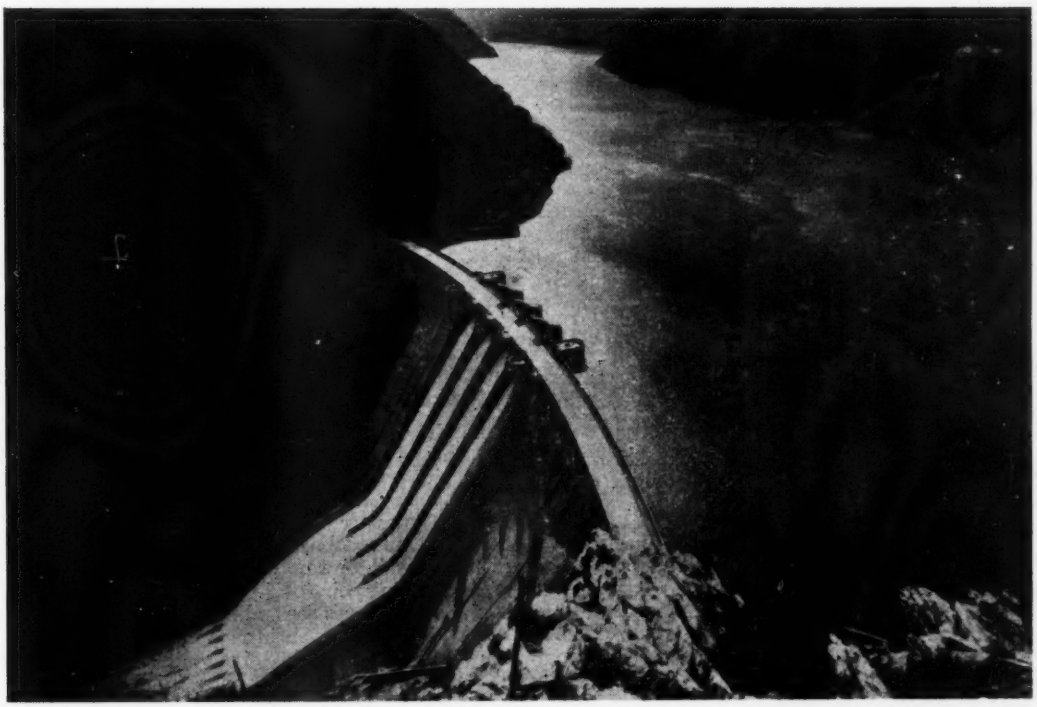
Salime Hydro-Electric Power Station in Spain

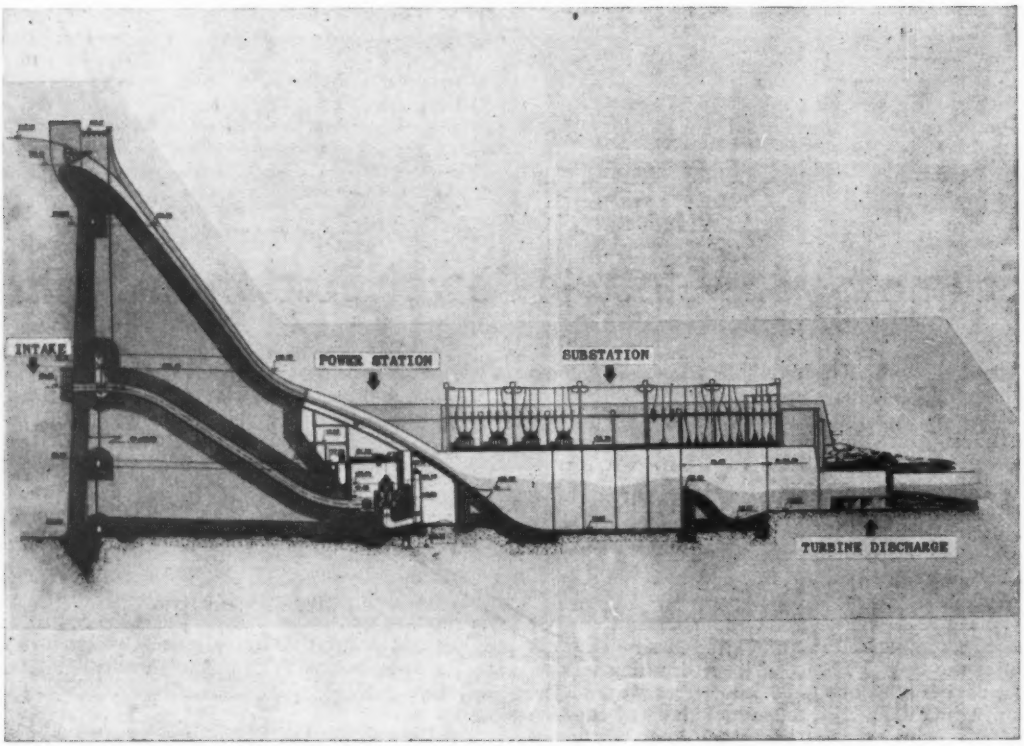
Part of the extensive hydro-electric developments which are taking place in Spain is the full exploitation of the River Navia in Asturias. This work is being undertaken jointly by two supply companies in the North of Spain, Electra de Viesgo S.A. and Hidro-electrica del Cantabrico S.A., whose headquarters are respectively at Santander and Oviedo. The construction work is being carried out by a subsidiary company named Saltos del Navia en Comunidad, created by these two companies for this purpose.

The river Navia rises in the mountainous district between Lugo and Ponferrada and flows northwards to enter the Bay of Biscay at a small fishing village, also called Navia, about 90 kilometres west of the port of Gijon. The river is short, judged by Spanish standards, being only 115 kilometres long, but in this distance it falls 400 metres. A total of five power stations are planned and these will help to supply the mining and industrial districts of Northern Spain, including the areas around Oviedo, Ujo and Santander. These five stations are (*a*) Doiras, built by Electra de Viesgo in 1934, containing three generating sets each of 20,400 metric h.p., 18,000kVA, (*b*) Salime, at Grandas de Salime, containing four sets each with a maximum output of 50,000 metric h.p., (*c*) Silvon, which will take its water from the Doiras Reservoir, the capacity and head of which is being increased by raising the dam crest by 3 metres. This station will contain initially one set of 44,750 metric h.p., 35,000 kVA, space being left for a second set, (*d*) Suarna, the furthest upstream, the project which is nearing completion, and (*e*) Arbon, a station planned downstream from Doiras to complete the exploitation of the river.

The English Electric Export and Trading Company was awarded the contract on the 1st January 1949 for the supply and erection at Salime Power Station of the four main turbine inlet valves, the four main

The reservoir and the dam





Vertical section through the dam and power house

vertical Francis type turbines with their draught tubes and auxiliary equipment, the four main 35,000 kVA alternators, the four main transformers, all 380 volts, 11 kV and 140 kV switchgear and the 11 kV power cables between the alternators and the 11 kV cubicles.

Subsequently, in November, 1955, the contract was placed with The English Electric Company for the first generating set for the Silvon station.

Salime Power Station was officially inaugurated by General Franco in August 1955 and it is at present being used as a peak load station. Paintings on the power house walls depict the changes that have taken place in the Navia river valley throughout the ages and illustrate the labours involved in harnessing the river to provide abundant electrical energy.

Salime Dam

The Salime dam is of the arch-gravity type, having a uniform triangular section throughout its length with a slope of 5% on the upstream face and 72% on the downstream face. The dam crest lies on a curve of 400 metres radius and its height above the foundation is 131.5 metres. The horizontal length of the crest is 250 metres and its width is 9 metres.

The penstocks for the four turbines are embedded throughout their length in the structure of the dam, each being about 90 metres long and having an internal diameter of 2.5 metres. Each pipe has an intake screen and an intake butterfly valve, the latter being accessible through a gallery in the dam. At the bottom end, each pipe is connected to a Straightflow main turbine intake valve.

The Power Station and Spillway

One of the interesting features of Salime hydro-electric power scheme is the design of the spillway, which flows over the power station into a stilling basin. This unusual layout was necessary because of the local topography.

The river Navia flows for the most part in a deep narrow valley through high mountains, the total catchment area being 1,806 sq. km. It is fed by melting snow as well as by springs and rainfall, under which conditions severe floods are to be expected at times, and the Salime spillway had to be built for a maximum flow of 2,000 cubic metres per second, despite the fact that the average flow of the river at Salime is only 51 cubic metres per second. Therefore, at maximum flow the spillway dissipates about a million horse-power and this must be done in a very narrow valley where there is a danger of landslides, and also avalanches in winter, due to the steep inclination (about 45°) of the strata and the slaty nature of the rock.

As there was not sufficient space for the power station and spillway side by side at the foot of the dam, the power station was placed there and the spillway carried over its roof discharging into a stilling basin. The water slides into this and flows along its bed until turned back on itself by the downstream retaining wall. A row of 'dragon's teeth' is located at the meeting point of the spillway and stilling basin so that the water is aerated before entering the stilling basin thereby preventing cavitation of its floor. The spillway is shaped to give a slight lift to the water as it passes over the power bouse in order to relieve to some extent the pressure at that point.

The surface of the spillway conforms to the curvature of the main dam. For this reason the four main generating sets in the power house lie on an arc of 310 metres radius. Consequently, the station overhead travelling crane rides on a curved track and has larger diameter wheels on the upstream end than on the downstream to compensate for this curvature.

Three main transverse bays are provided beneath the spillway. The power house occupies the middle bay, the tailwater chamber the bottom one, and the upstream bay houses the main control room containing control, metering and relay boards and all the 380 volt switchgear. A platform was made on the left bank of the river alongside the stilling basin to house the four main transformers and the 140 kV switching station.

The water in the tailrace chamber passes through a free flowing tunnel of 7 metres internal diameter, running underneath the substation, and discharges into the river just downstream from the counter-dam of the stilling basin, thus ensuring stable tailrace conditions.

Layout of the Power Station

The layout of the power station follows the normal 'English Electric' one-floor arrangement, in which all parts of the plant and equipment, including the main valves, come under direct access of the crane. The turbine centre line is at an elevation of 119 metres above sea level, and the station floor at 121 metres.

The width and height of the Power Station had to be kept as small as possible so that the spillway could be kept as low as possible, and by adopting a curved longitudinal horizontal axis instead of the normal straight axis, a considerable saving in these dimensions was obtained. In addition, two important departures from standard machine design were made to keep to a minimum the crane hook height necessary for lifting the rotor out of the stator; the turbine-alternator shaft was divided into three sections instead of the usual two and the pilot exciter was partly telescoped inside the main exciter. An important consideration when endeavouring to keep the height and width of the station to a minimum was that under no circumstances was it permissible to encroach on the 72% downstream profile of the dam.

The roof of the power house slopes due to the spillway. To keep the machine room dry, an apron was placed between the spillway channel and the power house roof to collect any seepage water.

Provision has been made for dismantling the turbine runner from below by making the throat of the turbine draught tube removable so that the runner can be lowered on to a special truck and then run out on rails to a pit, where it comes directly under the crane. A major maintenance overhaul of the turbine can thus be made without disturbing the alternator in any way.

Turbine Inlet Valves

The main turbine valves are of the 'English Electric' Straightflow type, having a bore of 2,130 mm. These valves present a straight and smooth pipe bore to the water when open but are always capable of closing safely in emergency since a hemi-spherical valve door cuts through the water without deflecting it. Water hammer is avoided by regulating the movement of the valve operating servomotor by a travelling control screw which progressively diminishes the speed of closing.

Interior of the power station showing the four 35,000 kVA generating sets

A double rubber seal is provided on the valves. The second seal enables inspection or replacement of the main rubber seal without emptying the water in the pipeline.

The Turbines

The four main turbines are of the vertical Francis reaction type running at 300 r.p.m., each giving a maximum output of 50,000 h.p. under a net head of 112.5 metres. The minimum working net head is 69 metres under which conditions each turbine gives 21,000 h.p.

The spiral casing of the turbine was welded to the speed ring in the works and then the whole assembly was divided into four parts for despatch,since the limits for transport to site were fixed at 47 tons or 5 metres wide × 4 metres deep due to the difficulties of approach to Salime Power Station. These sections were finally bolted and welded together at site and then tested before being embedded in the concrete foundations. The runner was fabricated, the runner blades being of stainless steel formed to shape before being welded to the runner crown and skirt. It has steel labyrinth water sealing rings. The guide vanes and their trunnions are of mild steel.

The regulating ring is of welded steel, with gunmetal gliding pads, and it is provided with cast iron guide vane levers and links and two steel rods directly connected to the operating servomotors. The governor follows the usual 'English Electric' principle, in which an actuator is driven by a pendulum motor and incorporates a speed adjustment device for synchronising and loading, and an underspeed device. It controls an oil-operated pilot servomotor which is itself fitted with a device for shutting down due to overspeed, low oil pressure, the operation of the electrical protection, or by push button from the control room. The pilot servomotor operates the main distributing valve which controls the oil to the twin guide-vane servomotors.

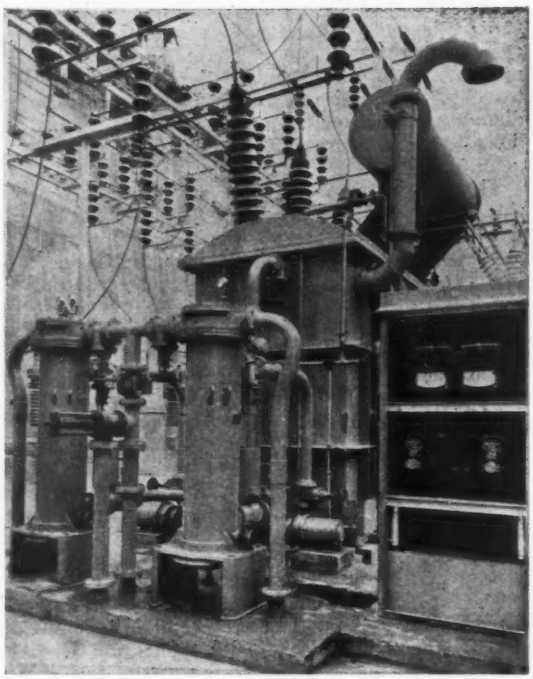
The Alternators

The four main alternators give an output of 35,000 kVA each at 0.9 power factor 11,000 volts 50-cycles, the speed being 300 r.p.m. They are of the vertical shaft two-bracket type, a combined thrust and guide bearing being mounted on the upper bracket above the rotor and a second guide bearing on the lower bracket below the rotor.

The stator frame was divided into two parts for transport to the site. The rotor was assembled at site by shrinking the steel hub packets on to the shaft and then fitting the salient poles on the hub. Both the poles and the hub are dovetailed and fitted with taper side keys in the slots in the rotor hub to facilitate removal for repairs.

Closed-circuit cooling is employed for the machines, the air being circulated by fans attached to the rotor and cooled by six water-cooled air coolers arranged tangentially outside the stator frame, instead of radially, to reduce the overall diameter as much as possible.

A governor alternator is mounted on the extension shaft directly above the thrust bearing, to supply a



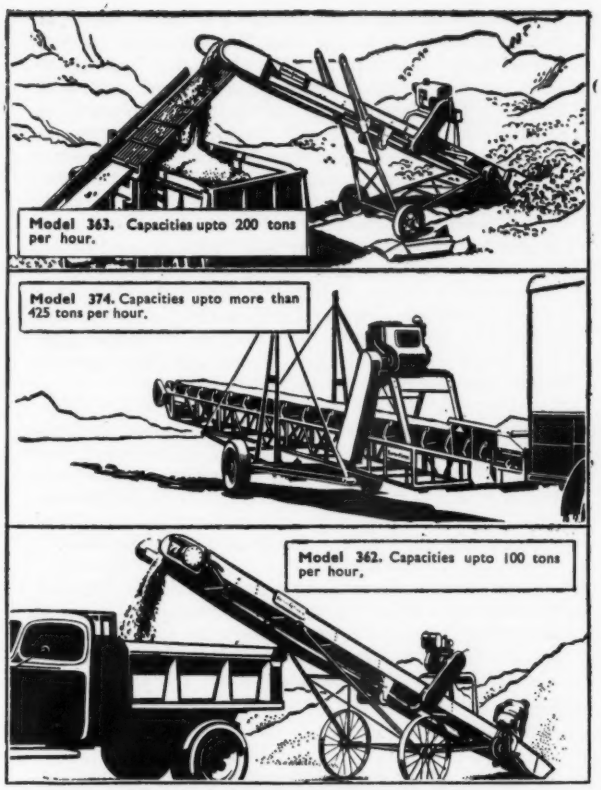
One of the four main 35,000 kVA transformers showing its two oilwater heat exchangers

synchronous motor which drives the turbine governor actuator pendulum. The main and pilot exciters are mounted on the same shaft, above the governor alternator.

The whole weight of the revolving parts, plus the vertical hydraulic thrust, is carried on a thrust bearing the pivoted pad type, mounted on the upper bracket, the load being transmitted through a thrust collar which is lightly pressed on to the shaft and secured by keys. The pads are pivoted to enable them to tilt freely in any direction and are also adjustable to ensure that each carries the same load. The upper guide bearing also has pivoted pads, which run on the polished vertical surface of the thrust collar. Both bearings run in a common oil pot through which the oil is circulated by an a.c. motor-driven pump, with a d.c. motor-driven pump as a standby. A second guide bearing, also of the pivoted pad type, is mounted on the lower bracket below the rotor, and this is included in the same lubricating system as the combined thrust and upper guide bearing.

The Transformers

The four main transformers are 3-phase units each rated at 35,000 kVA and having a no-load ratio of 11/140 kV, the 11kV winding being delta connected and the 140 kV star connected. Advantage has been taken of the fact that the neutral point of the system is solidly earthed to provide graded insulation on the 140 kV windings, with tapping points connected in the neutral end of the high voltage coils to give $\pm 2\frac{1}{2}\%$ and 5% voltage variation. The tap-changer is manually operated from the exterior of the tank, and is padlocked to ensure that it is only operated by a responsible engineer.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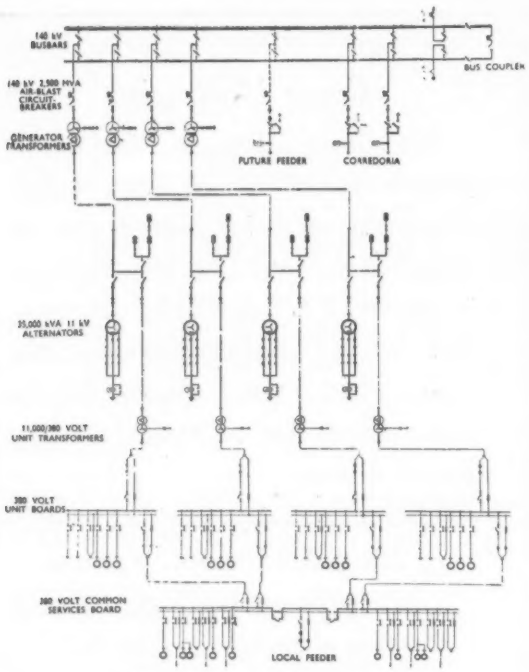
Cover Illustration

The illustration on the cover page is that of one of the two full revolving electric gantry cranes supplied to D.V.C., by M/s. Eastern Equipment & Sales Ltd., Calcutta. The main specifications of the cranes, which were ordered for the concrete placing in Maithon Dam, are as follows :—

Lifting Capacity (in short tons)	
at 125 ft. radius	**.. 14 tons.**
at 40 ft. radius	**.. 40 tons.**
Centres of rails	**.. 30 ft.**
Maximum lift	**.. about 200 ft.**
Lifting speed—	
20 tons load	**.. 200 ft/min.**
40 tons load	**.. 50 ft/min.**
Slewing speed	**.. about 1.2 r.p.m.**
Travelling speed	**.. about 100 ft/min.**

These cranes were installed early in 1954 and, working under different strenuous conditions, have since placed about 0.3 million cu. yards of concrete on the dam. After completing the work at Maithon Dam the cranes have been shifted to Panchet Hill Dam of D.V.C. for similar work there. The cranes are thus playing their part faithfully towards the construction of these two dams of Damodar Valley Corporation which when completed are bound to add to the strength and prosperity of the country.



Main electrical connections

The transformer oil is cooled in two oil-water heat exchangers, each of which is adequate for continuous full load operation. Provision is made to change from one cooler to the other without interruption of the circuit or change of load. The oil is circulated by means of a pump, which keeps the oil pressure in the cooler above that of the water to ensure that in the event of leakage there shall be no risk of the oil becoming contaminated with water.

There are four 800 kVA unit transformers, each with a no-load ratio of 11,000/380 volts, and these were manufactured by a Spanish company. Each is capable of supplying all the auxiliary and common services requirements of the station.

Switchgear

The unit arrangement was adopted for the power station, in which each set normally runs independently of the others and supplies its own auxiliaries at 380 volts by means of a unit transformer connected direct to the alternator.

The 11 kV switchgear consists of isolators housed in cubicles for isolating each alternator from its main transformer and also for disconnecting the feed to the unit transformer if desired.

With the exception of the governor oil pump, alternator and turbine main lubricating oil pumps and the alternator heaters, all the main machine auxiliaries and other station and local services are supplied at 380 volts from the common services board which is fed from any one of the four 380 volt unit boards. These three oil pumps and the alternator heaters for each set are supplied direct from the unit board of the set. The unit boards and the common services board consist of air-break draw-out type circuit-breaker units and 'Combination' fuse-switch units. There is at present no auxiliary generating set to provide an alternative supply to the common services board, although provision has been made for such a supply to be connected to this board if considered desirable at a later date. If the station shuts down completely it is restarted by insolating the alternator of one of the sets and feeding from the140 kV busbars through a main transformer and the corresponding unit transformer to the unit board and from there to the common services board.

Because of the narrowness of the site for the outdoor substation alongside the stilling basin it was essential to use a 'high' type arrangement in which the isolators and busbars are vertically above the circuit-breakers, instead of adjacent to them as in a 'low' station. The station has duplicate 140 kV busbars.

The 140 kV circuit-breakers are of the 'English Electric' air-blast type, with two interrupters in series per phase, having a breaking capacity of 2,500 mVA. All the feeder breakers are provided with high speed auto-reclose control. Duplicate air compressor sets are provided to supply all the requirements of the substation.

Power Development in Sudan

A significant development in the supply of electrical power in the Sudan took place on Thursday, February 28th, 1957, when the President of the Sudanese Supreme Council, His Excellency Siricio Iro Wani, formally opened the new Burri Power Station at Khartoum.

The new station provides the first electricity in the country to be gnerated by steam turbo-alternator sets. Previously electric power was generated entirely by diesel sets. Two 5,000 kW steam sets have already been installed and another 10,000 kW set is due to be commissioned in 1958. All the power sets in the Khartoum station steam as well as diesel, have been supplied by The English Electric Company.

The Government is considering the formation of the Sudan Electricity and Water Board to operate the electricity and water undertakings which have been developed over the past 32 years by two private companies, the Sudan Light and Power Company Limited and the Wad Medani Light & Power Company Limited.

Principal contractors, apart from the English Electric Company Limited, are Babcock & Wilcox Limited, Misr Concrete Development Company Limited and Power and Traction Finance Company Limited.

Manual Labour versus Machinery

The following extracts from the Report of the Construction Plant and Machinery Committee will be found of great interest as a contribution to the countrywide discussion among engineers on this important issue which is not only technical in character but also socio-economic in its implications: Ed.

The problem of unemployment in India is drawing pointed attention from everyone at present. Doubts are raised as to the value of mechanisation of projects to the country from the viewpoint of overall economy. We are of the opinion that a word of caution is necessary before going in for large scale mechanisation. We must find employment for the partially utilised vast resources of unskilled labour, particularly in the rural areas.

We must take into consideration, the drain on foreign exchange, which mechanisation brings about, not only for the purchase of equipment, but almost twice as much more for the supply of materials and spare parts needed to keep the machines running.

Our resources of skilled personnel to maintain and operate the modern mechanical equipment are limited and our organisational and administrative set-ups are not as yet modified to meet the existing needs of maintaining the equipment at a high standard of efficiency.

We consider that mechanised construction is indispensable under certain conditions for the quick and efficient execution of our projects. If the scope of mechanisation is limited to the proper spheres and does not interfere with the interests of manual work, the country would gain by the judicious use of machinery ; particularly now when the "Grow more food" works have to be pushed through and the quick execution of our River Valley Projects is very important to the nation's economy.

Before a project is planned for execution, the scope of mechanisation should be studied and limited to jobs which are not feasible without the aid of machines or which cannot meet the time schedules. For works which can be executed within the time schedules and to specifications, by either manual labour or mechanisation, the comparison of estimates will be the deciding factor. We suggest that for such works it would be undesirable to mechanise if the estimates for the machanised construction shows saving of about 20 per cent since, with the data available at present, overall estimates for mechanised work can be framed to approximately 80 per cent accuracy only.

A small amount of mechanisation to supplement the manual labour is our best arrangement. Selected items of work which can accelerate the progress of manual labour should be handled by machinery ; for example transport over long distance, lifting materials to the top of the dam, stone crushing for concerete, compaction of earth-fills, dewatering foundations, etc.

Production Schedules

The targets set for production schedules and the degree of availability of labour resources in a local area, are often guiding factors to decide the necessity of mechanisation. A two-yard excavator with about 10 men can do a job in a day which the same number of men would take a month to do. It is not always that a very tight time schedule is inescapable. If jobs are started well in advance, and time schedules are relaxed where it is reasonably possible to do so, it should be possible to avoid the necessity of rush-schedules on many jobs and thus bring them within the scope of manual labour.

This aspect should be borne in mind while preparing the progress schedules of construction for projects. The large amount of time consumed in planning for equipment and awaiting deliveries will often decrease time schedules sufficiently to enable the work to be done by manual labour.

The partially mechanised Tungabhadra Project and the highly mechanised Vaitarna Dam should provoke a lot of thought in this respect. The change-over from the use of mechanised concrete construction to masonry at Hirakud is another example for such analysis.

Specification Requirements of Modern Projects

Some of our modern projects are outside the scope of manual labour unassisted by equipment. Jobs such as Bhakra or the earthwork at Hirakud Dam, cannot be done without the use of modern machines. If we want the projects to be executed we must have recourse to mechanisation. Even if we were satisfied with completing our projects over an extended time, the specification requirements of such projects make it essential to use machines. It will not be safe to build them by other methods.

Special use of Mechanisation

Excavation for foundations, long leads, compaction to specification and tunneling in rock are spheres in which mechanisation seems indispensable even on medium sized jobs. Under-water excavation can best be done by draglines. Blasting below water table needs modern drilling and special explosive technique. Haulage over a distance of above 500 ft. cannot be attempted on any large scale without the help of transport vehicles.

Manual labour and trucks versus Earth-moving Machinery

Donkey transport can work to about two furlongs and works can be attempted with bullock carts up to a lead of one mile. But carts are getting scarce and costly for such work and the advent of motor trucks has almost completely taken over the transport of

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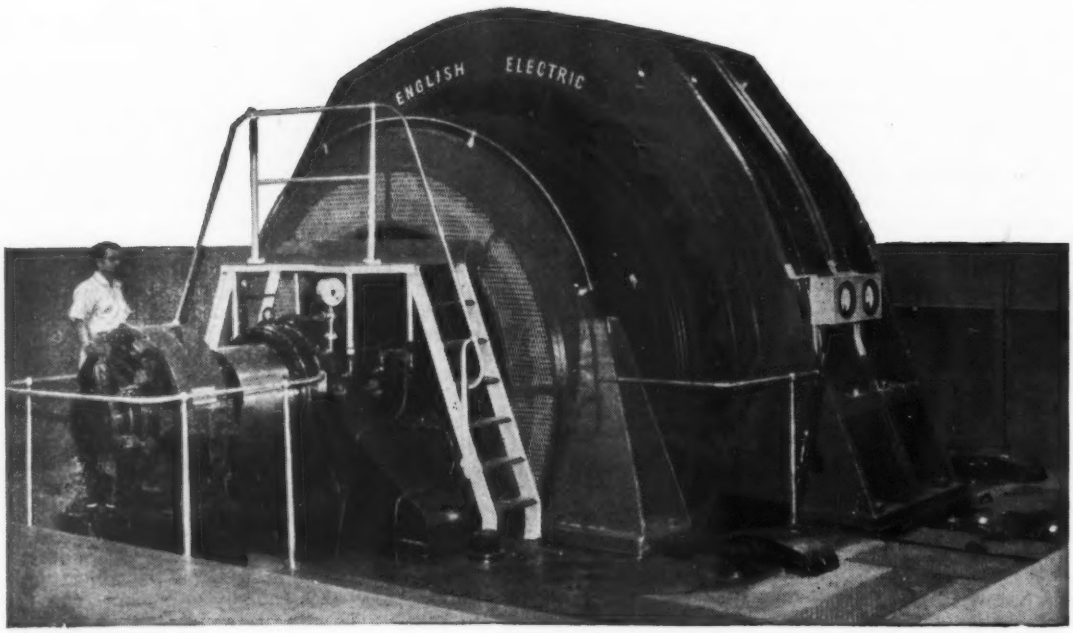

The illustration shows the 6650 H.P. Motor for the 40" Blooming Mill at the Indian Iron & Steel Works, Burnpur. In addition, the Company has supplied over 100 motors of various ratings to these Works.

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building materials. The motor truck transport is cheaper in initial cost but becomes more costly on running expenses with the result that on larger jobs it pays to go in for modern earth-moving equipment. A typical comparison of eathwork by trucks with that by heavy equipment is given in appendix 5.1 the conclusions evident from the study are as under :

(*i*) A large initial investment is required for earth-moving machinery which can be economically advantageous only when fully utilised. Comparatively little initial investment is required for manual excavation with truck transport

(*ii*) The labour strength employed and the construction colony for manual work will be nearly 15 times those required for earth moving machinery. The employment for manual work will be mostly unskilled labour, whereas that for earth moving machinery will be mostly skilled.

(*iii*) The unit rates of earthwork based on the total expenditure falls progressively as the earth-moving equipment is utilised for longer period of its life. The unit rates for manual work remains almost steady.

(*iv*) For jobs involving large quantities of earthwork spread over the life time of equipment, machinery work would be much cheaper than manual work.

(*v*) In this specific study, it would not pay to go in for earth moving machinery for less than 25 m.c.u. ft. of earth-work unless the salvage value of the equipment can be realised by further use or sale.

(*vi*) Continuity of construction by earth-moving machinery is essential to achieve low rates. For manual work, it does not affect the rates appreciably.

It is our contention that a non-technical critic does not realise the strength of labour required to do earthwork manually. If the earth work of the Hirakud Dam was to be executed by manual labour alone, the strength required would have been nearly 3,000,000. That would make a job impossible to set up or manage.

No shortage of labour in our Country

We, however think that specialised intricate equipment developed in the West to meet the shortage of man-power, should scarcely be necessery in India. For example, the trench diggers for shallow foundations of buildings, the field channel excavators (developed on All American Canal) or the elaborate rigs to dress the canal banks (used at Friant Project) would scarcely be required in our country. It is sad but true, that there is yet a certain amount of fascination in the minds of amateur engineers in doing jobs by machinery in fields which can be better covered by manual labour. It is necessary, therefore, to study critically each field of work before investing in machinery.

Our Economic Structure

The basic difference in the economic structure of labour in India and foreign countries is that an unskilled labourer costs us Rs. 30 to 40 per month whereas U.S.A. has to pay Rs. 1,500 per month. We have plenty of unskilled and little of skilled labour whereas the reverse is the case in U.S.A. On the other hand the imported cost of every dollar worth of equipment and spares is about Rs. 5 and 8 respectively. The value of spares required by the equipment is about 50 per cent of the cost of the equipment.

It is, therefore, wrong to arrive at the conclusion that if an equipment is developed in foreign countries to do economically a particular type of work there, it must be good for us also.

Necessity of improving Technique of Manual Labour

The modern conception of mechanisation is but an advanced stage in man's search for tools. It has contributed to the evolution of the world from the time of the caveman of the stone age. The development of the personal tools such as pick axes and the crow bars has been arrested by the over-loading effect of specialised equipment such as excavators. In advanced countries, the development of personal tools has taken the shape of pneumatic diggers, or electric hand drills. In India we have not yet given adequate thought to this problem.

Whereas the modern scrapers are a vast improvement over the earlier models of twenty years back, the small man's tools such as the spade or the basket have not been given enough attention for scientific development. The pre-historic method of transporting soil in little baskets carried over head has seen no improvement since the days of the pyramid. And yet these are the tools through which we are now planning to spend crores of rupees for our development projects. We entirely agree with the thought-provoking article sent from Washington D.C. by Shri, N. D. Gulati that a time and motion study of manual work needs to be pursued on scientific lines and that the workman's tools should be improved to give more performance and less fatigue. We quote the suggestions below :

"Briefly stated, the idea is that great saving would be obtained in most forms of engineering work involving the movement of earth by a thorough development of the science of earthwork under Indian conditions. Special study would be given, to the application, to the use of human labour, of the principles of time and motion analysis, which has done so much to increase production in the construction and manufacturing industries in this country.

"The second step in the study proposed, would try to bring about more efficient methods with the tools in common use by 'time and motion study'.....

"A great deal of study should be given to the best method of carrying out the studies. One of the first steps should be to get one or two experts in time and motion study from United States to come to India to see the conditions of work there and learn the problems involved.....

"Probably the best way to finance these studies, ...would be under the Point Four Programme. Another possibility would be under the Ford Foundation. A third but less desirable method would be for some time and motion expert to set up a study programme for himself at some University in India, under the Fullbright Act of the United States Government."

Labour Consciousness to their Amenities

A new aspect that has to be borne in mind in the

planning of large concentrated works managed by manual labour, is the labour consciousness for their elementary comforts and needs. It was possible in olden days to disregard the question of even modest housing, sanitation and health arrangements. Any concentration of labour today raises these fundamental problems. Even a bamboo matting hut costs over Rs. 250/- in construction and maintenance over 5 years. The cost of other services is nearly a third of of that. It will progressively become impossible to manage concentrated works without spending large amounts on construction towns. It is only a question of time before the demands of the labour unions in the field of industries pervade the sphere of the construction trade. In any comparison of manual labour versus machinery this factor must be carefully considered.

The difficulties normally encountered on jobs managed with manual labour have been summarised by Shri E. Viraraghavan, Superintending Engineer, Hyderabad, P.W.D. as under :

(1) Heavy Advances.
(2) Free transport from their villages to the work-spot and back after the completion of the season.
(3) More and more amenities.
(4) General decrease in the capacity of their work due to insufficient nutritive food.

He evaluates the economic effect of these over-head expenses on manual labour rates as under :

1. Hutting charges, providing mats bamboos, coir ropes, etc.	3%
2. Depreciation and mending of tools	1%
3. Transportation charges	3%
4. Watchman charges.	1%
5. Advances and food arrangements.	7%
Total	15%

If lighting, sanitation, water-supply, medical services, and the housing better than "bamboo and mats," are provided, the percentage will jump so high that it will be the critical consideration in the evaluation of overall economy. He further works out that the value of the food grains required is about 20 per cent of the value of the earth work.

Earthworks are more Economical

One of the reasons why large earthwork jobs are now attempted is the development, to a high standard, of the science of Soil Mechanics. An engineer can now use soil as a construction material with known factors of safety in the same way he used concrete or steel. This has made large earth dams technically feasible.

For the same height of a dam above the foundations, the quantity of earth required is roughly 10 times that of masonry. If, therefore, the rate of earthwork is 1/10th that of masonry, an earth dam will compete with a masonry dam in cost. In the matter of design the earth dam generally does not need to go deep below the ground level except for a small quantity (usually about 10 per cent) for the cut-off trench ; whereas a masonry dam has to start from sound rock however deep it is. This aspect works in favour of the earth dam. Usually the rates of earthwork are only about 1/10th that of masonry. This makes earth dams cheaper both in quantity and rates.

The development of earth-moving machinery has cut down the rates of earthwork whereas there has been a steady rise in the rates of other materials. To quote Donald and Auckland from "Moving Heaven and Earth."

"During 1920-30 period, earth-moving was accomplished by steam and gasoline units and was necessarily slow. Using a 1,000 ft. haul as basic the average delivery was 8 cu yds per man-hour at a cost of about 50 cents per cu yd. During the period 1930-33, the first true gasoline tractor was employed as a haul unit, and this increased production to figure of 12 cu yds. per man-hour at a cost of about 45 cents per cu yd.

"In 1933, when rubber tyres were introduced scraper performance was stepped up and production costs lowered. Hauling the same distance (1,000 ft.) during 1933-39 meant a delivery of 60 cu yds. per man-hour at a cost of about 14 cents per cu yd.

"In 1933, when Tournapull was invented a considerable saving both of time and money was effected. Production with this piece of equipment on a 1,000 ft. haul is 130 cu. yds. per man-hour at a cost of 8 cent per cu. yd. delivered."

In India, the rates of mechanised earthwork is only about 1½ times that of pre-war rates, but the rates of masonry has gone up to nearly four times.

We have collected information about some of the large works carried out by manual labour in the country.

Observation on Canal Earthwork

It is found from the statistics that the manual labour is utilised mostly for canal work and for minor earthen dams. The rates obtained for canal excavation by manual labour are on the whole such that mechanisation will scarcely be justified on the grounds of cost alone except where long leads and lifts are involved. We think that a good balance is obtained in this respect on our projects and no emphasis needs to be made for leaning more to either aide.

We would, however, suggest that there is a greater scope for the use of tramlines and tipping trucks for this type of work than has so far been employed. For large quantities of excavation for canals of small bedwidths in hard materials like the disintegrated rock, the use of back-hoes deserves more attention.

As regards the canal embankments, trucks used on highways are often employed for transport. These are unsuitable vehicles for off-the-road transport which need costly running charges. We suggest that for large works involving short distance transport, the use of small diesel shuttle dumpers 4½ to 6 yds. capacity loaded manually needs to be given more thought.

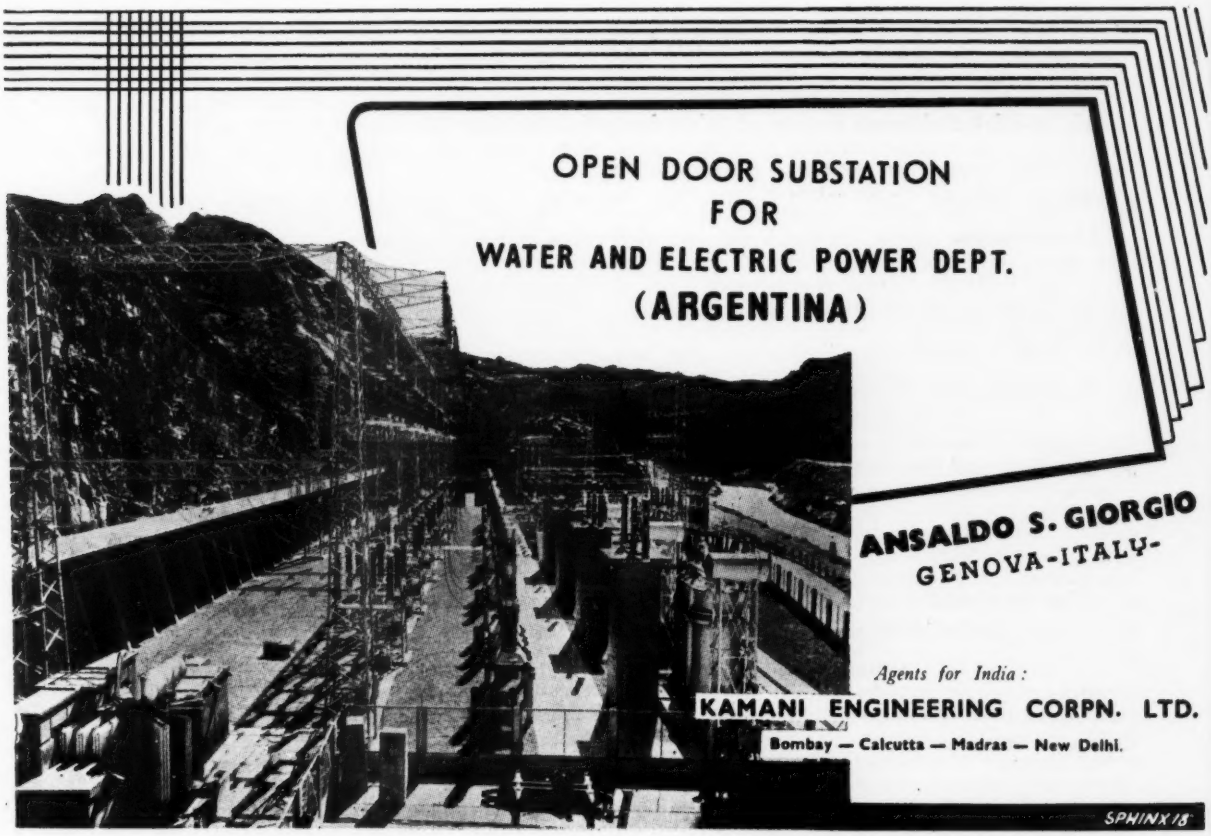
Observations on Earth Dams

For earthen dams, the transport is largely done by commercial trucks loaded and emptied by manual labour. The rates on the whole are higher than those possible with earthmoving machinery.

The Malampuzha dam is a typical example of con-

structing a small earthen dam with trucks. The overall rate works out to Rs. 93 per 1,000 cu. ft. of compacted bank. For this method of construction we think that the rate is satisfactory. But an all inclusive rate of about Rs. 60 per unit achievable by mechanisation even for somewhat longer leads and higher lifts. However, so long as such small dams are attempted as individual works, a higher degree of mechanisation is not desirable.

We think that a better planning should be possible by combining a group of small dam projects under a central mechanised organisation. If this can be done to pool about 50 m.cu.ft. of earthwork, mechanisation will cut down the cost and time. Utter Pradesh has already worked on this system successfully completing fair sized dams (30 to 60 m.cu. ft.) in one or two season each at attractive rates. Madhya Pradesh has planned in a similar way to construct a large number of minor irrigation works through use of Central Pool equipment. We feel that this type of planning deserves more investigation.



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Maximum rainfall intensity in different period intervals over Damodar Valley and a comparison of same with that over rest of Northeast India

By M. GANGOPADHYAYA, K. C. MAJUMDAR and A. KRISHNAN
Regional Meteorological Centre, Calcutta.

Introduction

With the prospect of availability of cheap power from the dams constructed across the Damodar and Barakar rivers, the chances of rapid growth of heavy industry in that minerally rich area have become very bright. In fact, depending upon the respective needs of the various industries, all types of meteorological queries on normal climatic conditions are already being received both from governmental and private sectors. Amongst these queries, the maximum possible intensity of rainfall in that area is almost a common one. Presumably this information is required for designing the factories and the drainage system of the attached townships. Besides the demands from the industrialists, the Hydrological Engineers of the Damodar Valley Corporation are also very keenly interested in this information. Using the average rainfall for the entire valley Pramanik and Rao[1] have given an estimate of average maximum intensity for period intervals of one to several consecutive days. No study has yet been made with regard to maximum intensity for period intervals shorter than 24 hours. Hence an attempt has been made here to estimate the maximum intensity in various period intervals by using whatever data are available.

Unfortunately we do not have sufficiently old data from self-recording raingauges in the valley in order to enable answer this question in a straight forward way. Jenkinson[2] has given a statistical method of estimating extreme values of meteorological elements for individual stations by using annual data of a relatively smaller number of years. But we do not have even that much of rainfall intensity data for the Damodar Valley area in order to enable us to apply Jenkinson's method. In order to get over this difficulty of paucity of data we have assumed that the entire area is meteorologically homogenous,—at least it is so with regard to the maximum possible intensity of rainfall and have applied the method of curve-fitting as described later.

The position of the self-recording raingauges in the Damodar Valley area together with their dates of installation is shown in Fig. 1. The ground contour of the area is also shown in this figure.

A reference to the climatological maps for Northeast India will reveal that the entire Damodar Valley area comprising of an area of about 7,000 sq. miles only lies in a vast area of metorologically homogenous conditions. In fact maps showing normal annual rainfall and other allied elements like number of days of rainfall and thunder which have a good bearing on intensity of rainfall also show this feature. A comparison of the average rainfall map with the topographical map referred to above does not seem to show any influence of orography on rainfall, presumably because the height of the high ground is not sufficiently high or the lie of the high grounds is such that it does not influence precipitation. Thus it will not be entirely unreasonable to assume that the entire area is homogenous so far as maximum rainfall intensity is concerned. It may be argued that if the area is homogenous with respect to intensity, then why do not we get same intensity recorded at all stations under a certain synoptic situation. Answer is, although the probability of occurrence of the same *maximum* intensity as possible under a certain situation is the same for all the stations, the actual intensity recorded at different stations is found to differ due to chance only. It will be seen later from the *smoothness* of the interval vice intensity curve (Fig. 2) that the assumption made with regard to homogeneity is not unjustified. It may be pointed out that consideration of all data available from all observation points situated in a homogenous area effectively increases the number of observations and consequently the sample.

Compilation of data

All the available data from self-recording raingauges of all the stations in the valley were tabulted in the usual way for finding out the amount of precipitation that had fallen in course of 5,10,15,20,30,40,50 minutes' intervals and also in 1-hour, 2-hour, 3-hour .....24-hour intervals. The highest value for each interval of time was picked up and the intensity per hour was calculated. The results are shown in Table I.

Procedure

For studying the variation of maximum intensity with the interval, the maximum intensity values tabulated above are also shown graphically in figure 2 where the maximum intensity in inches per hour represented by I has been plotted against the corresponding period of interval denoted by 't' in hours. The graph reveals that the variation of the maximum intensity with respect to period of interval is perfectly represented by a rectangular hyperbola. The very fact that almost all the points lie on the same smooth curve not only justifies, as already stated, our basic assumption about the homogeneity but also suggests the existence of a simple relation between I and t after a suitable transformation. From our everyday experience it is quite easy to understand in a qualitative way that the maximum intensity of rainfall calculated from precipitation recorded for hsorter period intervals would be greater than that calculated

Table I

S.No.	*Station which gives the maximum intensity*	*Date on which occurred*	*Period of interval (t)*	*Actual amount of maximum rainfall occurred in period 't' in inches*	*Maximum intensity of rainfall in inches/hour (I)*	
					Actual	*Estimated*
1.	Ramgarh	22.8.53	5 mins.	0.79	9.480	9.516
2.	Ramgarh	22.8.53	10 mins.	1.19	7.140	7.454
3.	Dumri	6.9.54	15 mins.	1.59	6.360	6.311
4.	Barhi	21.9.52	20 mins.	1.76	5.280	5.551
5.	Panchet Hill	8.9.53	30 mins.	2.39	4.780	4.550
6.	,,	8.9.53	40 mins.	2.67	4.005	3.910
7.	Asansol	26.9.56	50 mins.	3.04	3.648	3.451
8.	,,	26.9.56	1 hr.	3.42	3.420	3.105
9.	Dhanbad	3.7.53	2 hrs.	4.97	2.485	2.044
10.	,,	3.7.53	3 hrs.	5.79	1.930	1.592
11.	,,	3.7.53	4 hrs.	5.86	1.465	1.344
12.	Pupunki	7.9.54	5 hrs.	6.16	1.232	1.186
13.	,,	7.9.54	6 hrs.	7.01	1.168	1.073
14.	,,	7.9.54	7 hrs.	7.14	1.020	0.998
15.	,,	7.9.54	8 hrs.	7.21	0.901	0.930
16.	,,	7.9.54	9 hrs.	7.31	0.812	9.877
17.	,,	7.9.54	10 hrs.	7.36	0.736	0.847
18.	,,	7.9.54	11 hrs.	7.49	0.681	0.810
19.	,,	7.9.54	12 hrs.	7.52	0.627	0.780
20.	Bokaro	5.7.53	13 hrs.	7.65	0.588	0.757
21.	,,	5.7.53	14 hrs.	8.03	0.573	0.735
22.	Asansol	26.9.56	15 hrs.	8.66	0.577	0.719
13.	,,	25-26.9.56	16 hrs.	9.95	0.622	0.704
24.	,,	25-26.9.56	17 hrs.	11.35	0.668	0.689
15.	,,	25-26.9.56	18 hrs.	11.84	0.658	0.674
26.	,,	25-26.9.56	19 hrs.	12.04	0.634	0.667
27.	,,	25-26.9.56	20 hrs.	12.64	0.632	0.652
28.	,,	25-26.9.56	21 hrs.	12.92	0.615	0.644
29.	,,	25-26.9.56	22 hrs.	13.08	0.595	0.637
30.	,,	25-26.9.56	23 hrs.	13.12	0.570	0.629
31.	,,	25-26.9.56	24 hrs.	13.14	0.548	0.622

Fig. 1. Map showing the catchments of Damodar and Barakar rivers with their topography. The positions of raingauge stations in these catchments are shown by numbers. Numbers within Circles indicate positions of S. R. raingauge stations, the names of which are given below:
Names: Damodar Catchment: 1 Hazaribagh 2 Bishungarh 3 Bokaro 4 Dhanbad 9 Chandwa 11 Ramgarh 14 Panchet Hill 16 Dumri.
Barakar Catchment: 3 Tilaiya Dam 4 Dhanwar 6 Palganj.
Lower Catchment: 42 Asansol.

from rainfall recorded during a longer period. But it is difficult to form an idea as to how the maximum intensity is related to the period of interval. The curve in Fig. 2, however, shows that it is possible to get a simple relation between I and t after some suitable transformation. So instead of trying to fit a hyperbolic equation of the form

$$I = a - b\frac{1}{t}$$ where I = intensity, t = period interval and a and b are constants.....(1)

We attempted a relation of the form

$$I = a - b \log\left(\frac{1}{t} - c\right)$$ .....(2)

as suggested by the plot of I against 1/t.

The constants of the equations of the type (2) cannot be obtained by the usual method of least square due to the presence of the constant "c" within the logarithmic term. The best way is to compute c from the ratios of the differences $I(=I_2-I_1)$ and $\left(\frac{1}{t}\right) = \frac{1}{t_2} - \frac{1}{t_1}$ (c.f. Brooks & Carruthers)[3]. Then using this value of c in (2) a and b are calculated by the method of least square considering log (1/t-c) as the independant variable. Following the above procedure, it is found that

$$I = 1.186 - 7.525 \log(1/t\text{-}0.8)$$ .....(3)

which has a multiple correlation coefficient, R = 0.997, which is so high that its test of significance required for the test of goodness of fit of equation (3) is unnecessary. Thus we have arrived at a very striking result that the relation between the maximum intensity I of rainfall in inches per hour and log(1/t-0.8) where t is the period of interval in hour is perfectly linear and is given by equation (3). This linear relation is represented by the straight line in figure 3. The straight line thus obtained fits very well with all

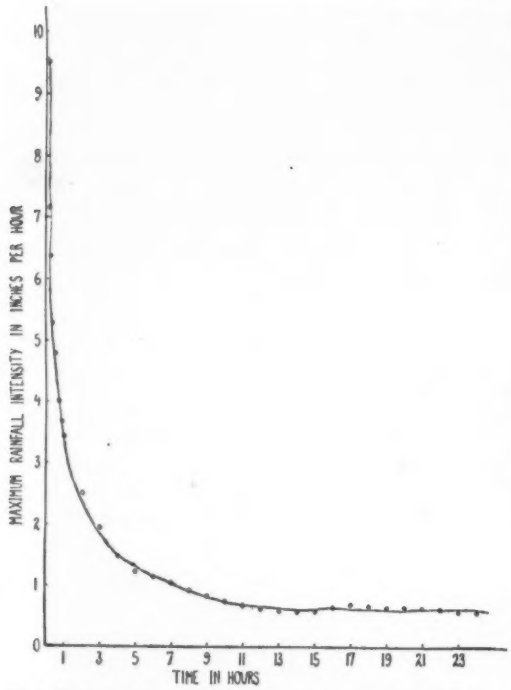

FIG. 2 *Maximum intensity of rainfall in various ranges of time in D.V. area.*

the observed points. The point corresponding to the maximum intensity for the period of interval of 5 minutes, which has the highest degree of confidence being based on the greatest number of observations (not less than 1000) coincides the line given by equation (3). The maximum intensity of rainfall for any other period of interval can be easily found out either from the equation (3) or graphically from figure 3. Those values obtained from this relation for the different periods of interval are also shown in Table I along with the actuals used in deriving this equation

Distribution of maximum intensity of rainfall in 24 hours over different years

The above relation between the maximum intensity of rainfall and the period interval has been derived from data of a relatively shorter period. But we have got daily rainfall data of a much longer period and from those data we can at least check up whether the value of I corresponding to the 24-hour period interval as estimated by the above method compares favourably with that calculated from the highest daily rainfall figure. With this object in view, the maximum rainfall in 24 hours (ending at 0830 hours. IST of a day) has been found out from the daily rainfall data of all the available raingauge stations in Damodar Valley area for each of the 32 years from 1924 to 1955. These maximum rainfall together with the corresponding intensity in inches per hour are shown in Table 2. It is seen from this table that the highest intensity of rainfall for 24 hours period, recorded during 32 years is 0.519 while that obtained from the self-recording rainfall records of 12 stations during years from 1948 to 1956 is 0.548 considering rainfall for 24 hours from any hour to the corresponding hour next day instead of 0830 hrs. to 0830 hrs. next day and that estimated by the realation (3) is 0.622 inches per hour. It will be shortly shown from the study of distribution of these intensities that the highest value viz. 0.622 as given by the relation (3) may be considered to represent the highest possible value with sufficient accuracy for all practical purposes.

The statistical criteria β_1, and β_2 and a= (mean deviation)/ (standard dvevation)[4] are then computed to judge whether these maximum intensities for 24 hour interval obey normal distribution or Gumbel's distribution (Kendall) law. These quantities are found to be :

$\beta_1=0.284$, $\beta_2=3.252$ and a=0.735

From the tables for the percentage points of the distribution of $\sqrt{\beta_1}$, (=b_1) and of a (Pearson and Hartley)[4] it is found that the maximum intensity of rainfall for 24 hours does not follow normal distribution, while it obeys the Gumbel's distributiou law as could be seen from Tipett's[5] calculations on β_1, and β_2 for this distribution when n, the number of observations, is 32.

Using the relation (4) (Brooks and Carruthers)[3] below, a few percentage points of the Gumbel's distribution $F(y)=\exp(-e^{-y})$ of the maximum intensity of rainfall in inches per hours for 24 hours period have been calculated as shown in Table 3.

$$Y = 1.283(I-\bar{I})/\delta+0.577$$
$$=15.0199I-4.2383 \quad \ldots\ldots(4)$$

where $\bar{I}$=mean of I's =0.3206
and δ=standard deviation of I=0.08542

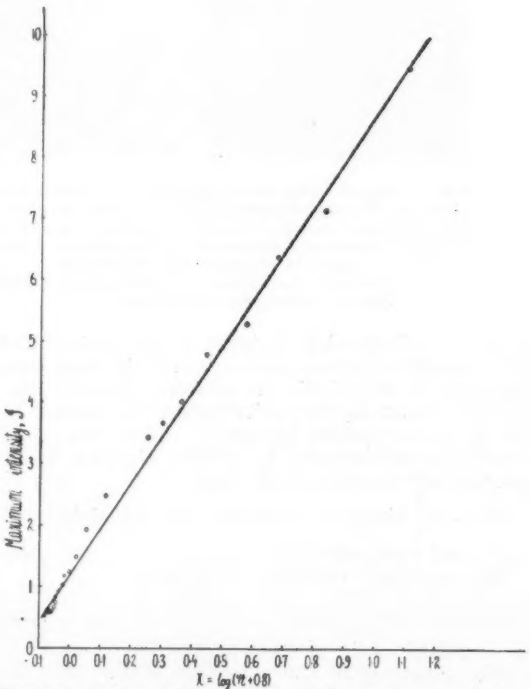

FIG. 3 *Relation between maximum intensity of rainfall, I in inches per hour in D.V. area, and the corresponding period of interval, t in hours with I expressed as a linear function of* $\log(Yt+0.8)$. *[equ. n]*

Table 2

Table: Maximum rainfall in 24 hours based on data of all stations in Damodar Valley area during 32 years from 1924 to 1955

S. No.	*Year*	*Station*	*Date/month*	*24 hours highest rainfall in inches*	*Maximum intensity of rainfall in inches/hour*
(1)	(2)	(3)	(4)	(5)	(6)
1.	1924	Dhanwar	17/9	6.05	0.252
2.	1925	Jamtara	24/7	5.48	0.228
3.	1926	Chandwa	5/9	7.80	0.325
4.	1927	Balumath	5/9	7.50	0.313
5.	1928	Jamtara	8/10	7.94	0.331
6.	1929	Topchanchi	24/8	7.48	0.312
7.	1930	Hazaribagh	9/7	8.26	0.344
8.	1931	Asansol	2/7	6.60	0.275
9.	1932	Barhi	5/8	4.79	0.200
10.	1933	Jamtara	23/7	7.56	0.315
11.	1934	Kodarma	12/7	7.21	0.300
12.	1935	Topchanchi	12/8	8.70	0.363
13.	1936	Jaipur	25/9	7.67	0.320
14.	1937	Kodarma	30/7	8.36	0.348
15.	1938	Tundi	15/6	3.70	0.154
16.	1939	Raghunathpur	4/8	6.22	0.259
17.	1940	Chas	28/8	6.70	0.279
18.	1941	Panchamba	10/10	6.05	0.252
19.	1942	Barhi	10/8	7.33	0.305
20.	1943	Barhi	4/8	11.62	0.484
21.	1944	Tandwa	24/8	10.32	0.430
22.	1945	Tundi	26/6	4.40	0.183
23.	1946	Barhi	18/9	10.38	0.433
24.	1947	Kodarma	1/8	12.34	0.514
25.	1948	Dhanbad	20/7	7.03	0.292
26.	1949	Balumath	19/7	12.45	0.519
27.	1950	Danea	18/7	8.35	0.348
28.	1951	Nirsa	11/9	7.33	0.305
29.	1952	Mandar	17/8	8.34	0.347
30.	1953	Hazaribagh	6/7	8.73	0.364
31.	1954	Mandar	8/9	8.20	0.342
32.	1955	Kodarma	17/8	5.33	0.222

Table 3

Values of F, the probability of the maximum intensity in 24-hour period in Damodar Valley area being $\angle$I. :

I	0.306	0.365	0.431	0.483	0.548	0.622
F	0.500	0.750	0.900	0.950	0.982	0.995

From this table it is seen that the probability of the maximum intensity being greater than 0.548 is only 0.02 which is extremely small. In other words, a maximum intensity of 0.548 as obtained from 9 years' data of self-recording charts of all Damodar Valey stations may be exceeded only once in 50 years. As a matter of fact, this has not been exceeded in 32 years considered. It is also noticed from this table that the maximum intensity of 0.622 inches per hour will be exceeded 5 times in 1,000 years or once in 200 years, the probability of the maximum intensity 0.622 being 0.995. The odd of this value (0.622) of the maximum intensity is so small (1 in 200) that for all practical purposes this may be considered to represent the highest maximum intensity of rainfall for 24 hours period with sufficient accuracy. It may be recalled that this intensity is predicted by the relation(3). In view of this, it may be concluded that the maximum intensity of rainfall given by (3) in any period of interval will rarely be exceeded and may therefore be considered to represent the highest maximum intensity in the respective period of intervals.

Table 4

Station	*No. of year on which result based*	*Hourly maximum intensity in inches/hour*	*Estimated by the above method*
Calcutta (Alipore)	16	2.90	
Dum Dum	4	1.73	
Gaya	10	1.89	3.11
Jamshedpur	10	3.38	
Saugor Island	10	2.72	

Similarly, the maximum intensity corresponding to the 24 hour period interval has also been calculated from the highest of daily rainfall so far recorded amongst all the stations in the plains of Northeast India which have daily raifall data over a large number of years (40 to 60 years). This value comes out to be 0.650 inches per hour recorded at Bogra while the value estimated from equation (3) above is 0.622 inches per hour (vide Table 5). Thus it is seen that the estimate made in this paper for Damodar Valley area which, meteorologically speaking is situated in a much less rainy area than the area in which Bogra is situated, compares quite favourably. This lends an additional support to the finding of this study.

Table 5

Maximum intensity of rainfall for 24 hours period for different stations in Northeast India based on 30 to 60 years' data.

S.No.	*Station*	*Maximum intensity in inches/hour*	*S.No*	*Station*	*Maximum intensity in inches/hour*
1.	Calcutta	0.605	13.	Silchar	0.476
2.	Saugor Islands	0.589	14.	Dhubri	0.604
3.	Jamshedpur	0.261	15.	Gauhati	0.382
4.	Sandheads	0.548	16.	Tezpur	0.243
5.	Midnapore	0.343	17.	Sibsagar	0.359
6.	Burdwan	0.491	18.	Dibrugarh	0.367
7.	Krishnagar	0.482	19.	Ranchi	0.354
8.	Berhampore	0.469	20.	Darbhanga	0.437
9.	Malda	0.333	21.	Purnea	0.522
10.	Dinajpur	0.447	22.	Gaya	0.398
11.	Pabna	0.373	23.	Bogra	0.650
12.	Balasore	0.569	24.	Jalpaiguri	0.640

Comparison with the values from plains of Northeast India

It will be interesting to see how the maximum intensity value corresponding to the period interval of 1 hour obtained in this study compares with the actuals from stations in rest of Northeast India as have self-recording raingauge data for a much longer period. Table (4) below shows the comparison. The value estimated by equation (3) for Damodar Valley area is in close agreement with the actuals for rest of Northeast India.

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A Healthy Experiment

Out of the travail and tension following the nation-wide controversy on the issue of redemarcation of State boundaries in India, if there has arisen a significant constructive idea it is the one regarding the formation of Zonal Councils. It is an attempt at arresting the autarkic trend of the States which if led to its logical conclusion would have tended towards the balkanisation of the country. The Zonal Councils are regional Inter-State forums "without impinging on the legislative and executive authority either of the Centre or of the States. This would provide in each Zone a common meeting ground where the States could be associated with each other to promote and facilitate cooperative effort towards the economic and social development of each zone and towards the unity and welfare of the nation as a whole." (G.B. Pant). Some of the Zonal Councils have been holding their first meetings recently and the pattern and texture of their structure and manner of functioning was attempted to be set down by the Home Minister, Sri. G. B. Pant in his inaugural speeches. If the constructive and democratic spirit which informed most of his suggestions pervade the further deliberations of the Zonal Councils, we are sure that much of the harm caused by emergence of a provincialist outlook may be halted if not undone.

We who are specially interested in the promotion of rapid resource development of the country on an integral and planned basis, welcome the creation of Zonal Councils as incorporating the regional idea, howsoever partially, which we have been pleading for a long time through these columns. We are particularly glad that even in the first meetings of these councils special attention was devoted to the problems of cooperation in such fields as irrigation, power development, soil conservation in the upper catchments of rivers, pooling of technical manpower, resettlement of persons displaced by reservoirs, common electricity tariff policy, common policy on water rates and on crop planning, inland navigation, etc. For example, the Northern Zone has under its purview such items as the problem of soil conservation in the catchment area of the Sutlej River in Himachal Pradesh in order to protect the Bhakra Project, specially the Nangal Hydel Canal. Or again, the Nangal Hydroelectric Grid cuts across the boundaries of Himachal Pradesh, Punjab, and Delhi. The utilisation of the power potential of 3.5 lakhs kilowatts of power generated and supplied by this Grid needs to be planned all over this Northern Zone on a long term basis. Similar and other issues are bound to be considered by other Zonal Councils. This is a most healthy development and we fully share Sri. Pant's view when he says : "The success of the Zonal Council's experiment would depend to a large extent on the *outlook* which the State Government brought to bear on their deliberations, their ability to appreciate each other's point of view and their readiness to reconcile the State aspect of different problems with their Inter-state aspect."

It may not be known to many that when this Journal planned a symposium on Power and Water Resources Development of West Bengal, one of the items that was initailly included for discussion was the "Problems of Cooperation between Adjacent States" in the matter of resource development. At that time we were discouraged by higher authorities to include this item as being controversial. But it has been our persistent viewpoint that natural resource development efforts must be based on the cooperative endeavour of all relevant factors concerned and considerations political should as far as possible remain in the background. For, firstly, resource development in an underdeveloped region must receive most prior consideration by all and would be advantageous to the entire community in the region ; and secondly, it is essentially a technical and scientific task and other considerations should intervene in the least. We are now gratified that the Government of India has given high priority to Inter-State cooperation in the matter of resource development. The All India Power Engineers' Conference held recently at Bangalore, sponsored by the Ministry of Irrigation and Power, has also rightly stressed on the urgent necessity of zonal planning of power development.

Inter-State project have one great merit in that they create the economic preconditions for the social and economic inter-dependence of peoples of different cultural, linguistic and geographic backgrounds. The DVC and the Bhakra Nangal and the Tungabhadra are obvious examples. But even these get threatened if their is no parallel efforts at intermingling of minds, of cultures. If the politics within each State gravitates towards linguistic and cultural puritanism in the future, then these structural efforts at "emotional intergration" may not be able to bear the strain. It is therefore necessary that side by side with this zonal cooperation in resource development on governmental level, the leaders of the country gave their attention to improving the tone and strain of the politics within each State, so that the two parallel cooperative efforts bear the desired fruit. This is a task not only of those in power but also of those who are not.

Soldering Aluminium Cables

Aluminium Union Limited have recently published an 84 page instructional handbook entitled "Soldering Aluminium Cables" which gives step by step illustrated instructions on the joining methods now most popular. The Appendices contain rating tables for aluminium cables. Interested engineers and jointers please write to Aluminium Union Limited, 41, Chowringhee Road Calcutta-16, for copies of this handbook which will be supplied free of charge.

First 100 kV Impregnated Pressure Cable Installation In Asia

Early in 1955 the Tata Power Company awarded BICC the contract for the supply and installation of over 16,500 yards of 3-core 100 kV Impregnated Pressure cables. It was finally decided that the installation should consist of two 3-core cables, each capable of carrying up to 90 mVA (about 120,000 horse power), laid together through 4.1/2 miles of congested streets in the Bombay Port area from Sewri Fort to the new Carnac Receiving Station. Surveys were carried out and then the actual installation work commenced in October 1955. Due to the climatic conditions, no work was possible during the heavy monsoon rains and operations were, therefore, stopped in June 1956, to be started once again in October of the same year. The installation was completed by the end of the year and both cables were charged in 1957. The switching-in ceremoney, however, took place on 4th April, 1957.

As this was the first use of such high-voltage cables in India, the contract presented several novel problems. Difficulty was experienced in transporting the cable drums, each weighing over 13 tons. This particular problem was finally solved by modifying an ex-military tank transporter and using this for loading, carrying and unloading the drums. In all, 52 drums were handled by this means.

High temperatures and excessive humidity, which are features of the Bombay climate, made it desirable that all jointing should be carried out in a controlled atmosphere. In order to achieve this, specially designed portable jointing tents were constructed locally on a heat-insulating material and two 1-ton air conditioners were fitted in each joint bay. The aluminium mobile site office, too, was fully airconditioned. Power for air conditioning, lighting and general purposes was supplied by a number of mobile diesel generator sets.

Largest Transformers ever Built

Two of the largest transformers ever built have been ordered by the Tennessee Valley Authority from English Electric Company for the Authority's new power station at Gallatin, Tennessee.

Their capacity is 345,000 kVa each and they are to transform the generator pressure of 13.8 kV upto the transmission voltage of 165 kV.

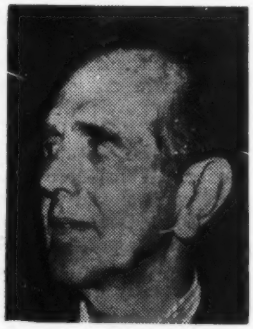
Mr. Walter Wehtje—Managing Director of Atlas Capco Gooup retires on April 13th

WALTER WEHTJE

On April 13th 1957, Mr Walter Wehtje retires from the Atlas Copco Group. Since he joined as Managing Director in 1940 this organisation, then known as Atlas Diesel, with headquarters in Stockholm has grown into an international group of compressed air engineers.

In 1898 Atlas made the first of a series of diesel engines which gained them a world reputation. An Atlas engine powered the famous Polar exploration ship, Fram. A dual production policy enabled them to manufacture also compressors and pneumatic equipment.

In 1948 Mr. Wehtje sold company's diesel interests to Nydquist & Holm to enable Atas to concentrate on compressed air engineering. This decision was based on the belief that pneumatic equipment would be needed in vast quantities for the many postwar development projects and the industrial expansion which was beginning all over the world. The growth of the Group testifies to his judgement. In 1946 Atlas had three companies overseas, now there are twenty-eight.



KURT ALLAN BELFRAG

The symbol of success for his company has been the lightweight rock drill which was introduced in 1947 and which made possible the Swedish method of Tunnelling. This method, now known to civil and mining engineers everywhere, is based on the use of one-man drills instead of heavy equipment needing two/three operatives.

Following a policy of 'seeing for himself' Wehtje has travelled many thousand of miles every year by air. Now 60, he has always believed in appointing young executives. The average age of his Managing Directors overseas is 39.

His successor is 49 year old Kurt Allan Belfrag who was appointed Deputy Managing Director of the world Group in 1955.

In India Atlas Copco is represented by Vulcan Trading Company (Private) Ltd. Bombay, Calcutta, Madras and New Delhi.

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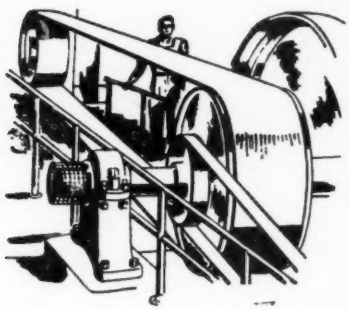

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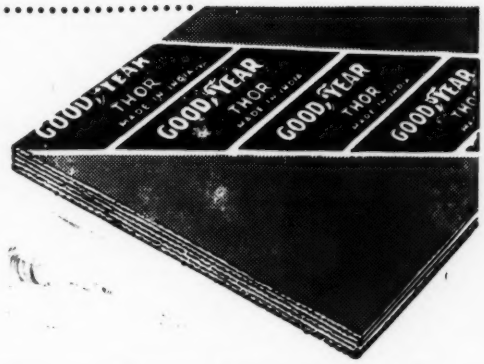

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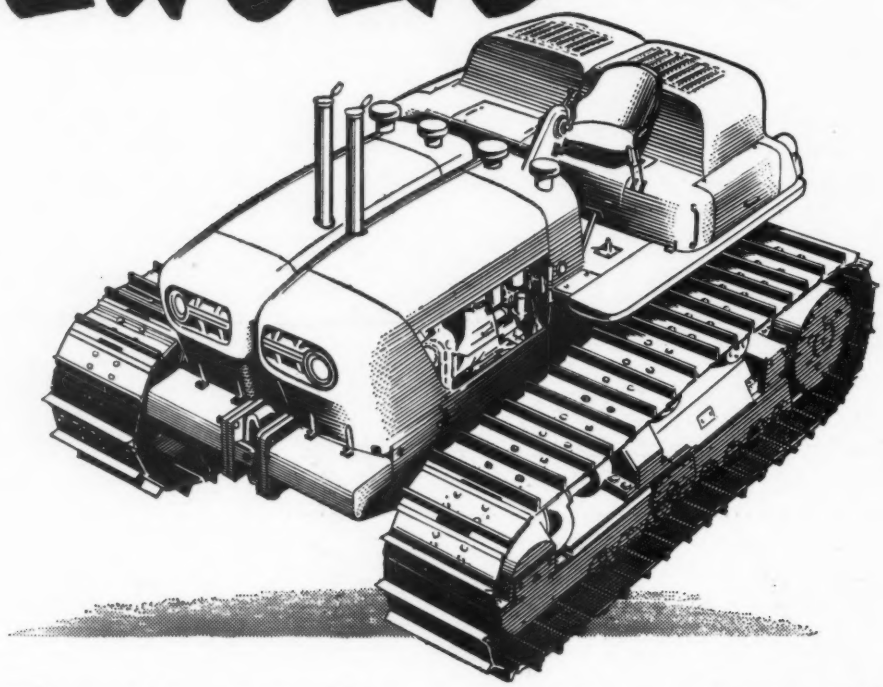

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